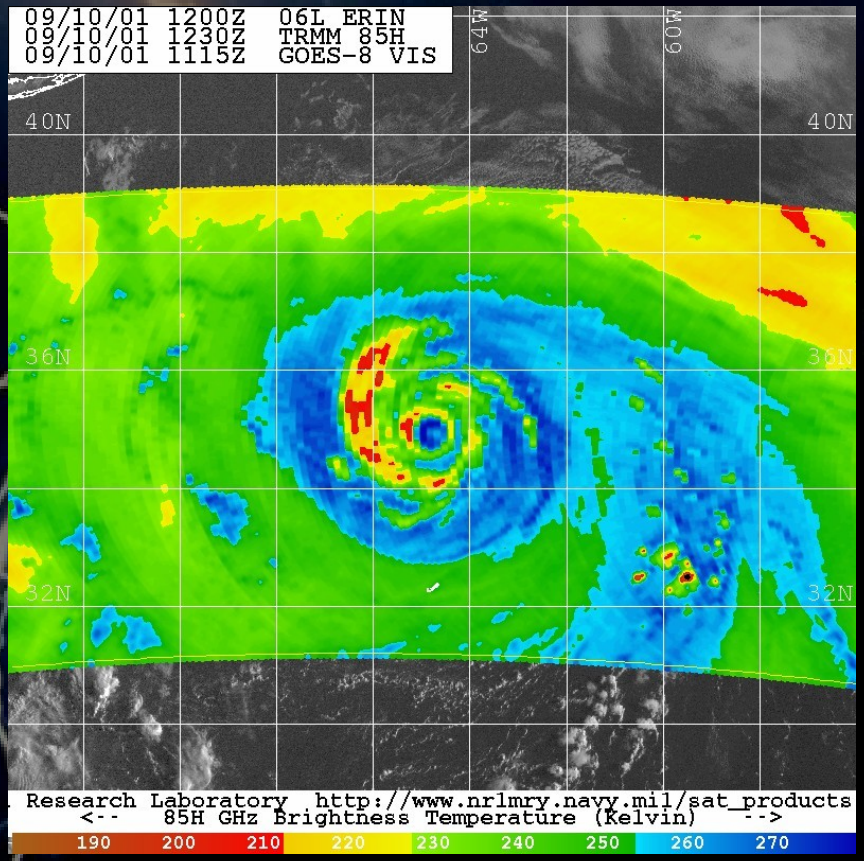
Satellite Meteorology

Part IV

Microwave Sensing



Objective

Understand the basics of microwave sensing, to include passive and active sensing, the products produced by the LEO sensors, and the applicability of these products.

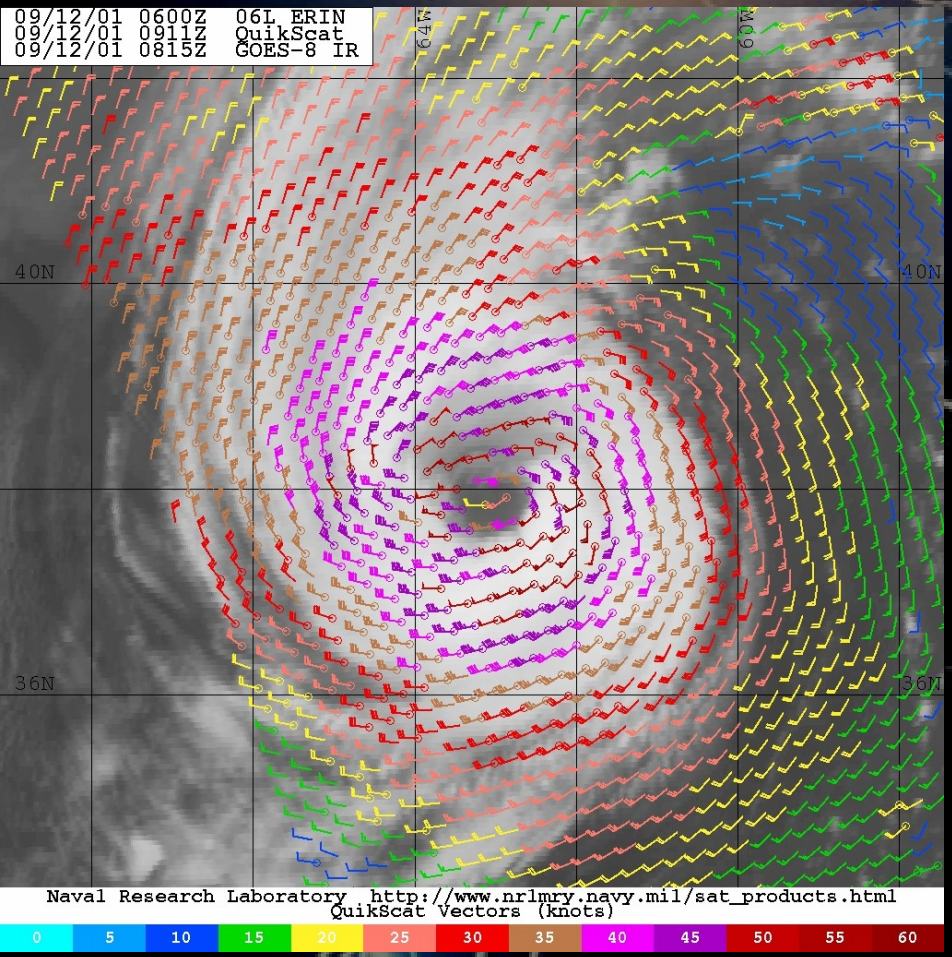
Microwave Sensing

- Active vs. Passive
- Passive
  - Advantages
  - Limitations
  - Microwave retrievals
- LEO
  - Scanning Strategies
  - Sounder vs. Imager
- Current Operational Passive Microwave Satellites

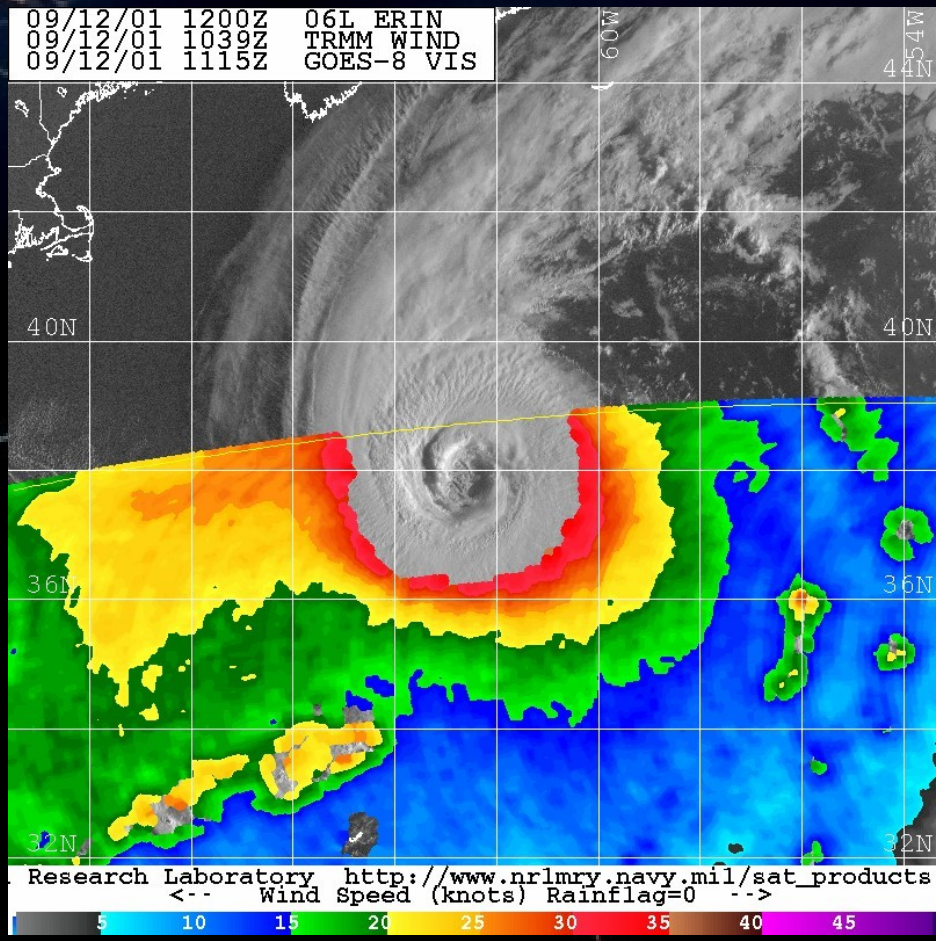
Active vs. Passive Microwave Sensing

- “Passive” indicates receipt of naturally-occurring microwave energy from the atmosphere and surface of the earth.
- “Active” indicates the use of a powered antenna to transmit and receive microwave energy (“weather radar” in space).

“Active” QuickScat Wind Speed and Direction

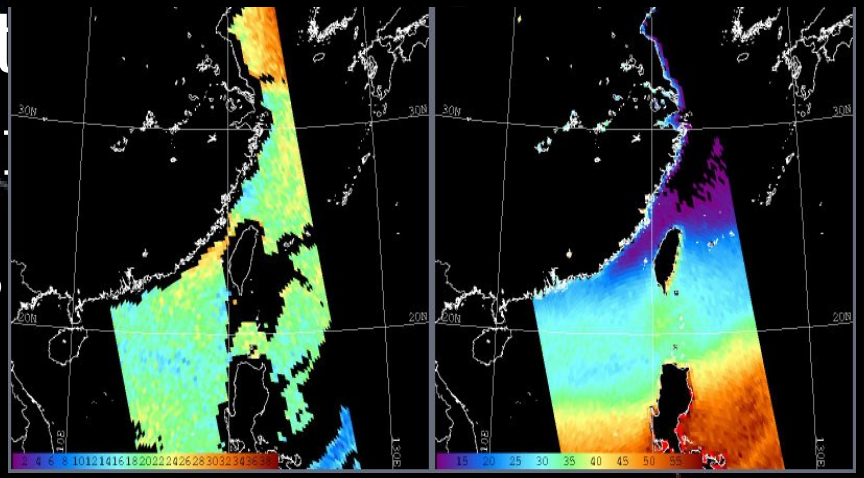

09/12/01 0600Z 06L ERIN
09/12/01 0911Z QuikScat
09/12/01 0815Z GOES-8 IR
40N
36N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
QuikScat Vectors (knots)
0 5 10 15 20 25 30 35 40 45 50 55 60

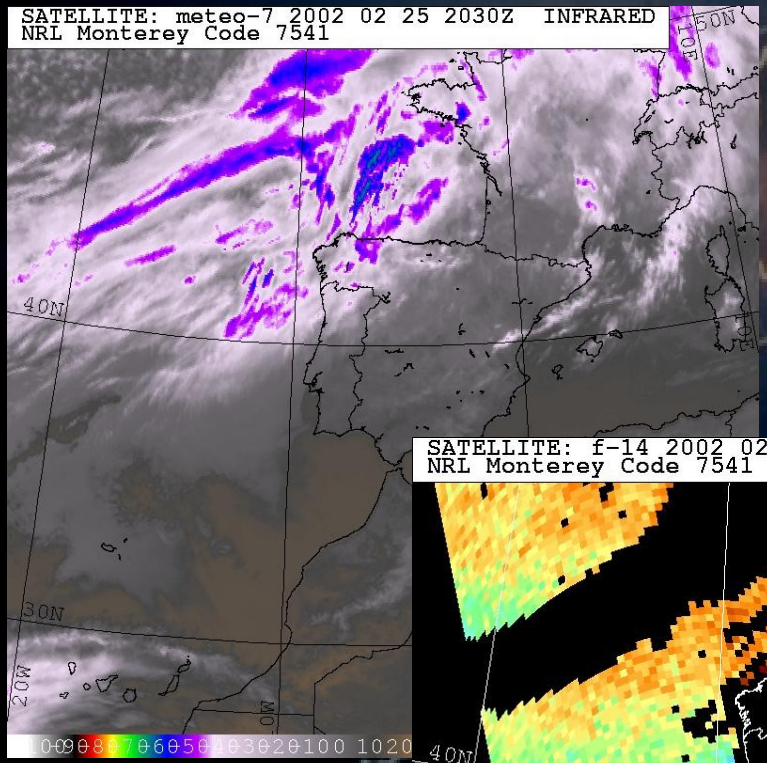
“Passive” TRMM TMI Wind Speeds

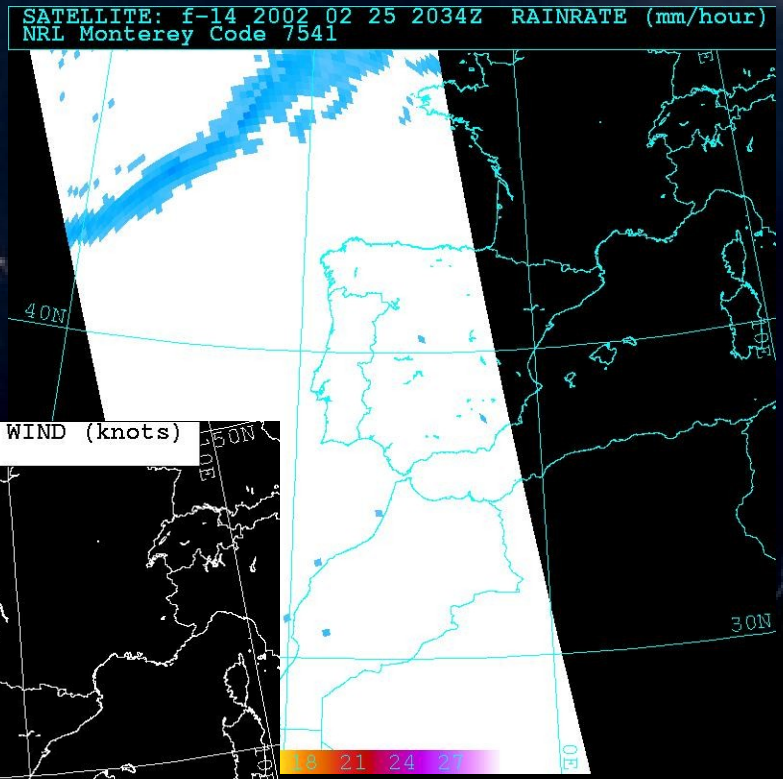


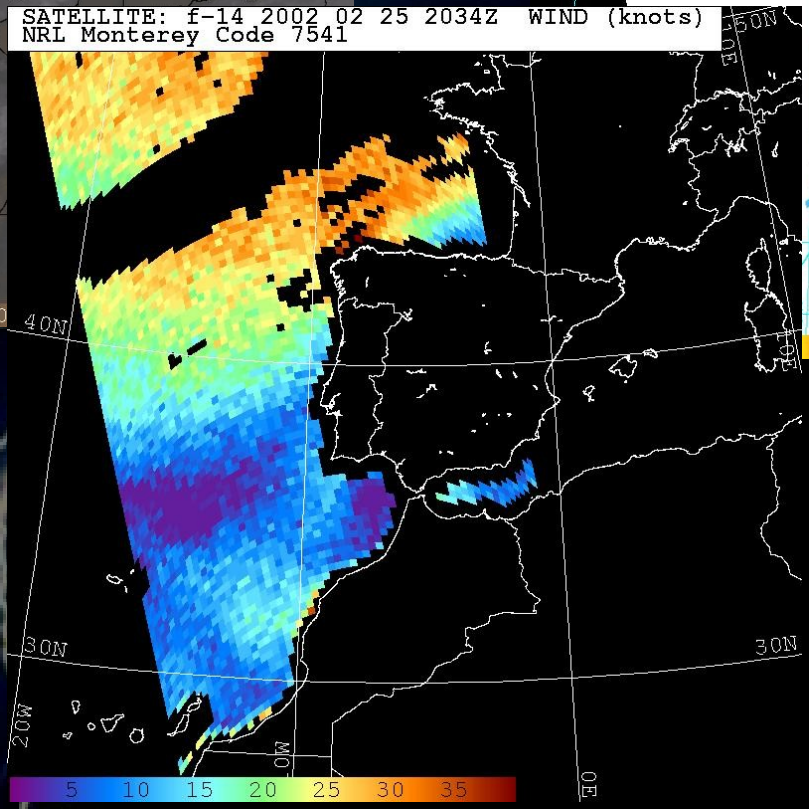
Advantages of Passive Microwave

- Cirrus clouds are transparent, allowing view of low clouds, precipitation, and the surface of the ocean/land.
- Quantitative est
  atmospheric pa
- Marine emphas




SATELLITE: meteo-7 2002 02 25 2030Z INFRARED
NRL Monterey Code 7541
50N
40N
30N
20W
10W
0
10E
100 102


SATELLITE: f-14 2002 02 25 2034Z RAINRATE (mm/hour)
NRL Monterey Code 7541
40N
30N
18 21 24 27
0E


SATELLITE: f-14 2002 02 25 2034Z WIND (knots)
NRL Monterey Code 7541
50N
40N
30N
20W
10W
0
10E
5 10 15 20 25 30 35

Limitations

- Narrow Swaths
- Infrequent Refresh
- Large footprint sizes at lower frequencies because of lack of sufficient energy
- Coastline Contamination (side lobes)
- Over water only

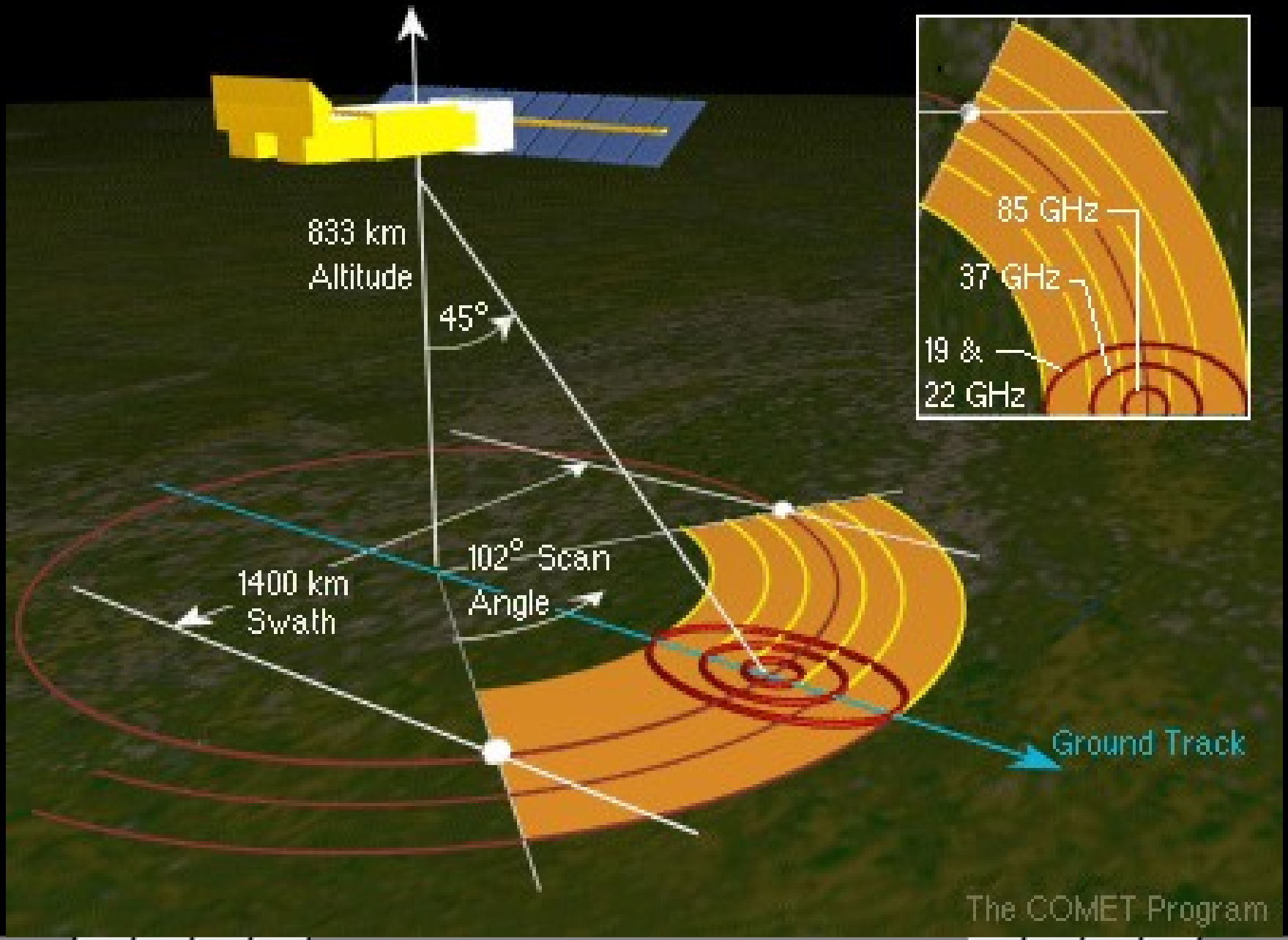
Passive Microwave Products

- Atmospheric:
  - Cloud Liquid Water
  - Precipitation Intensity
  - Total Precipitable Water
  - Water Vapor/Temperature Sounding
- Ocean
  - Surface Wind Speed
- Ice
  - Amount, Edge, and Age

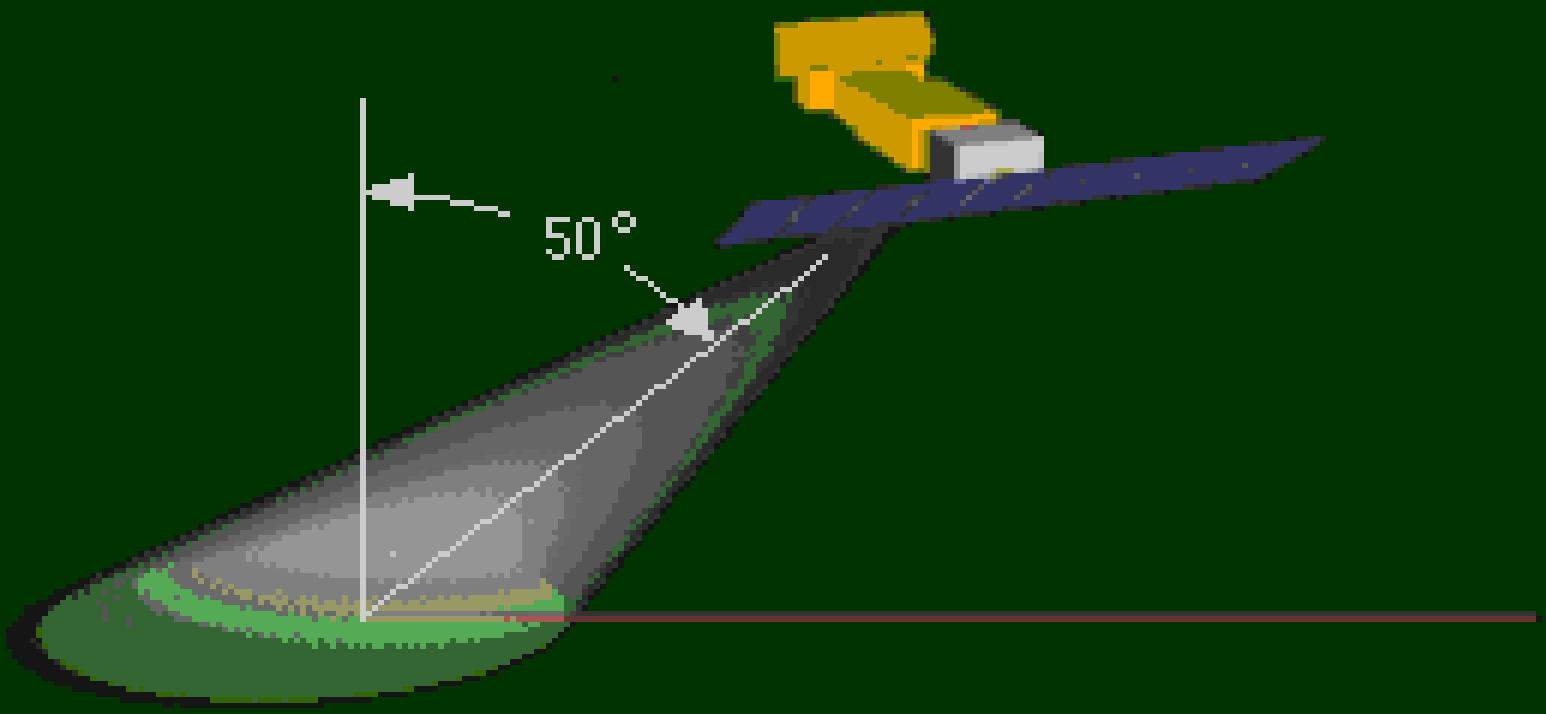
Scanning Strategies of Low Earth Orbiting Satellites

Two Strategies:

- Forward-looking Conical Scan Angle (constant footprint size): SSM/I and TRMM TMI
- Cross-scan (varying footprint size) AMSU A-B


833 km
Altitude
45°
1400 km
Swath
102° Scan
Angle
Ground Track
85 GHz
37 GHz
19 &
22 GHz
The COMET Program

AMSU Scanning



The COMET Program

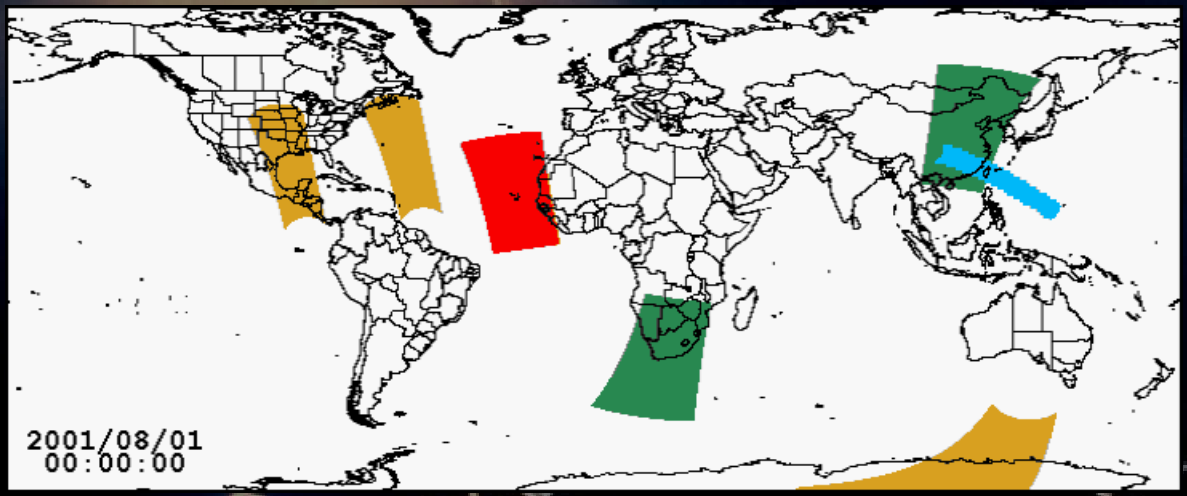
Current Operational Satellites "Passive Microwave"

- DMSP Special Sensor Microwave (SSM/I)

  F 13-15
- NOAA Advanced Microwave Sounding Unit (AMSU) N 15-16-17
- NASA TRMM Microwave Imager (TMI)

Examples, Rain (TRMM), Tropical Cyclones, Wind

Daily Coverage from Low-Earth-Orbiting Satellites



(click on image to animate)

Accumulated Number of Overpasses

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Colored Regions represent 10-minute coverage

Gold SSMI (1400 km) from DMSP F-13, F-14 or F-15
Red MODIS (2400 km) from EOS-Terra (Aqua)
Green AMSU-B (2400 km) from NOAA-15 or NOAA-16
Blue TMI (760 km) from TRMM

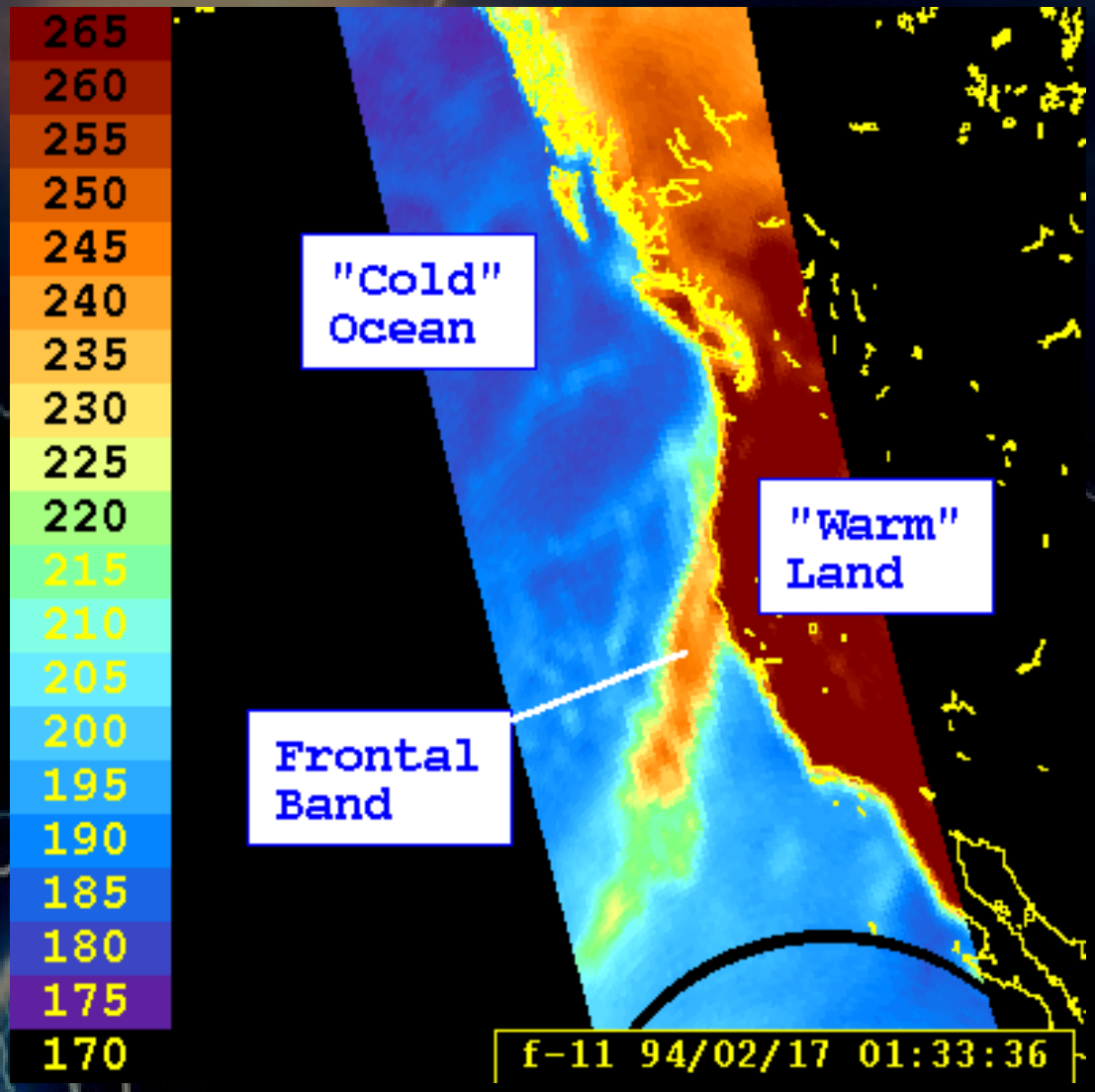
DMSP Satellites

- Defense Meteorological Satellite Program
- 4 meteorological sensors
  - OLS Visible and infrared imager
  - SSM/I Microwave imager
  - SSM/T1 Temperature sounder
  - SSM/T2 Water vapor sounder

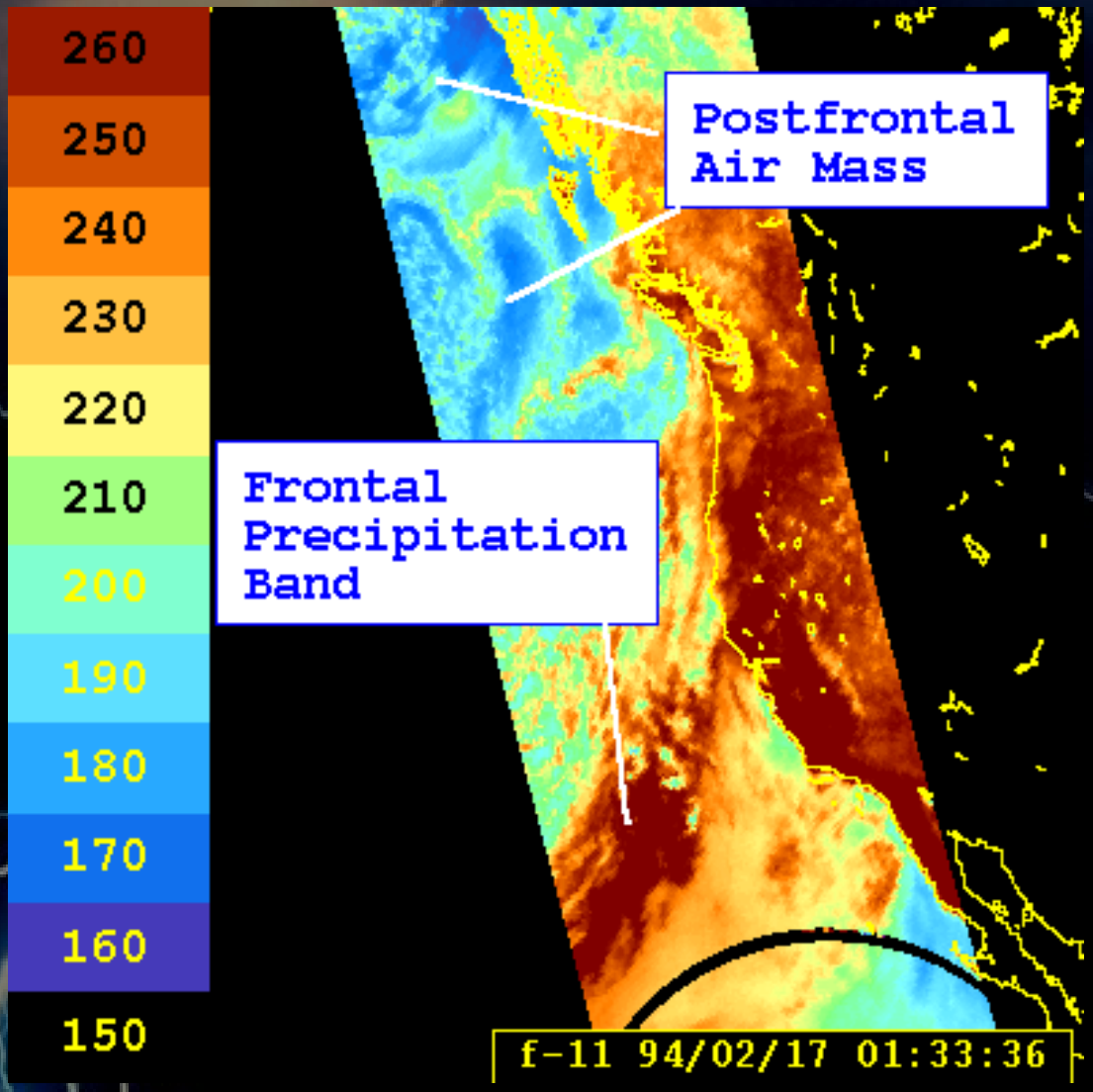
SSM/I Raw Channels

- 85 GHz V, H (widely imaged) 16 x 14 km
- 37 GHz V, H (algorithms) 38 x 40 km
- 22 GHz V, H (algorithms) 60 x 40 km
- 19 GHz V, H (algorithms) 70 x 45 km

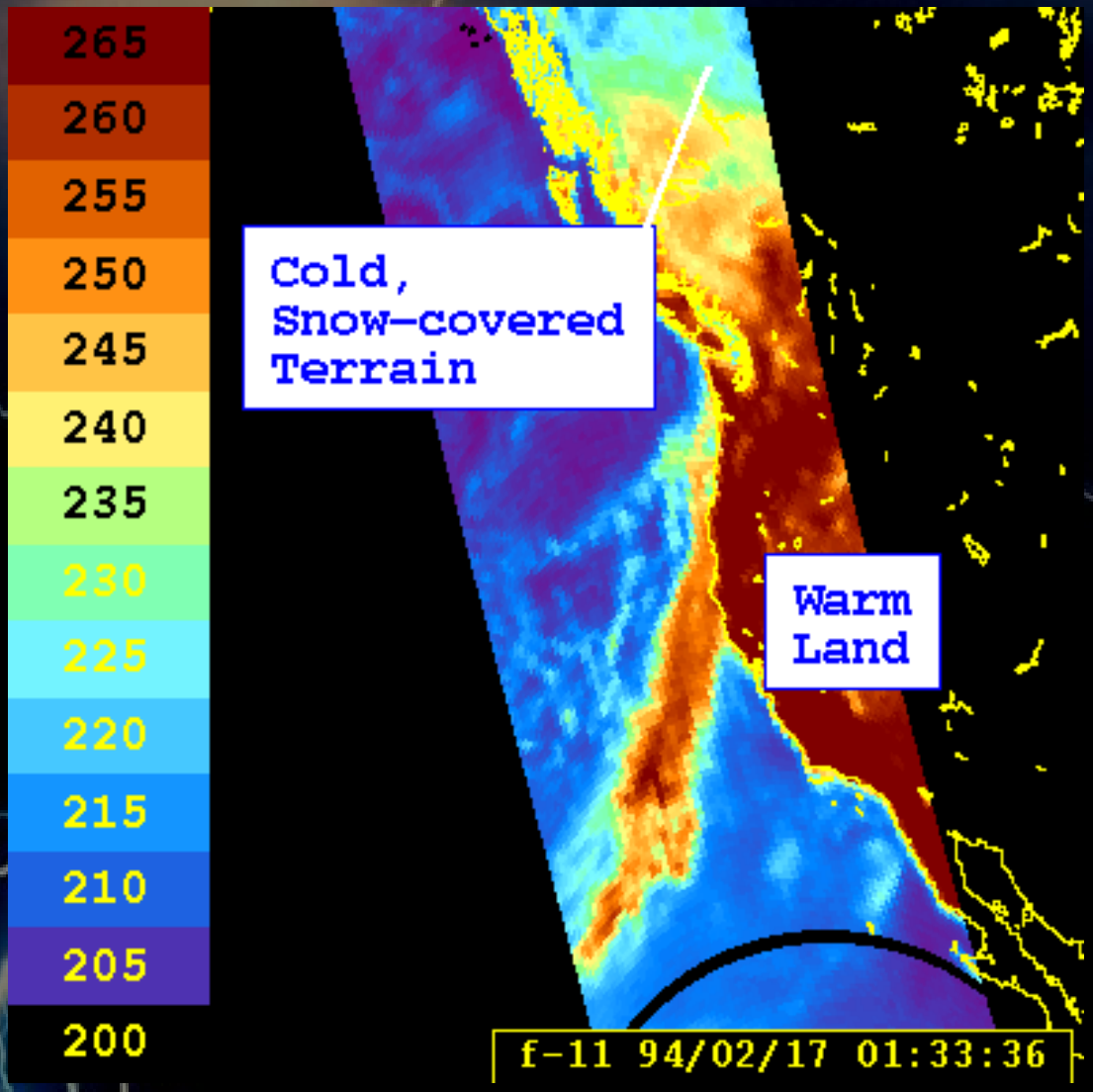
SSM/I 19V GHz


265
260
255
250
245
240
235
230
225
220
215
210
205
200
195
190
185
180
175
170
"Cold" Ocean
"Warm" Land
Frontal Band
f-11 94/02/17 01:33:36

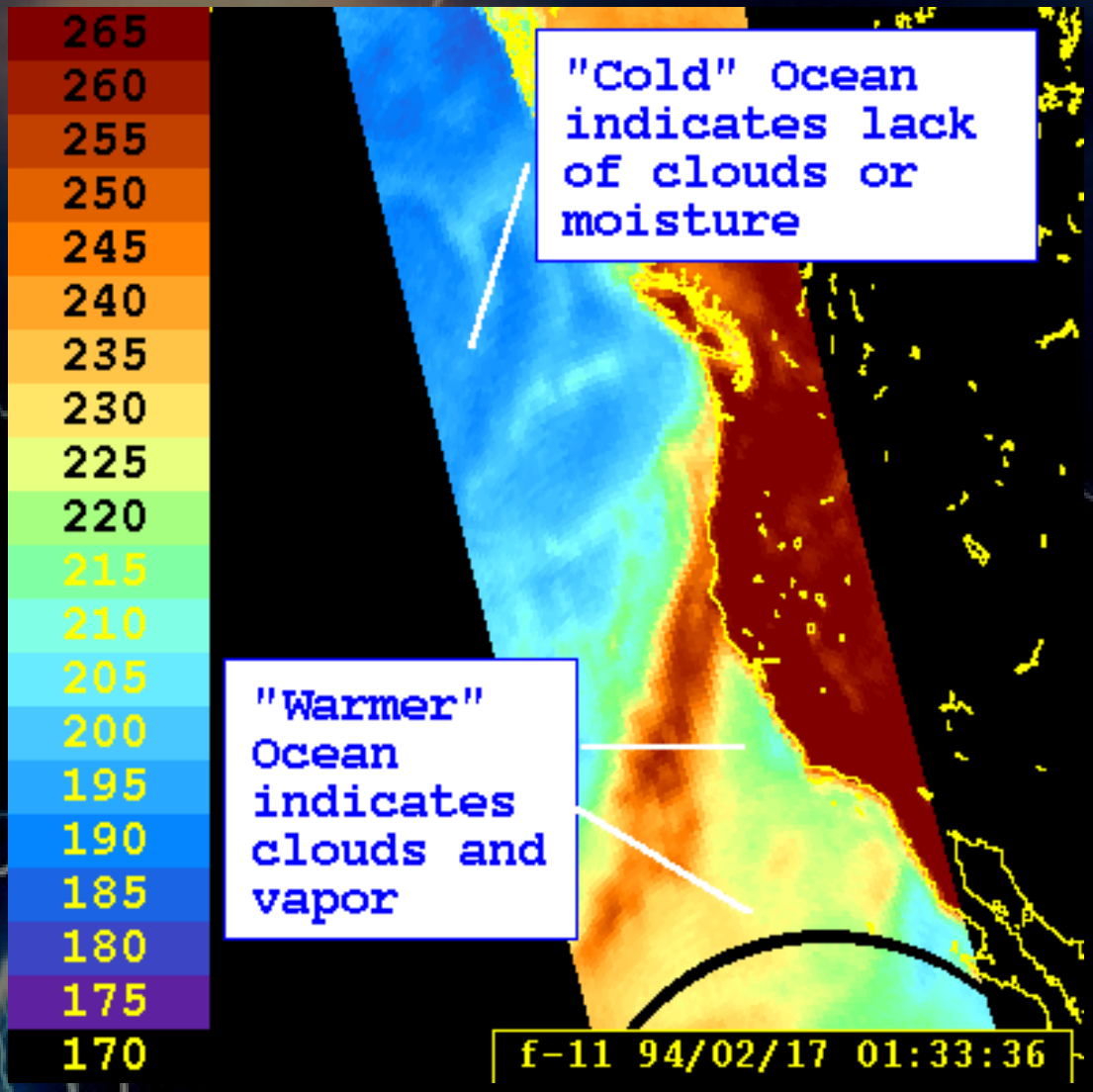
SSM/I 85V GHz


260
250
240
230
220
210
200
190
180
170
160
150
Postfrontal Air Mass
Frontal Precipitation Band
f-11 94/02/17 01:33:36

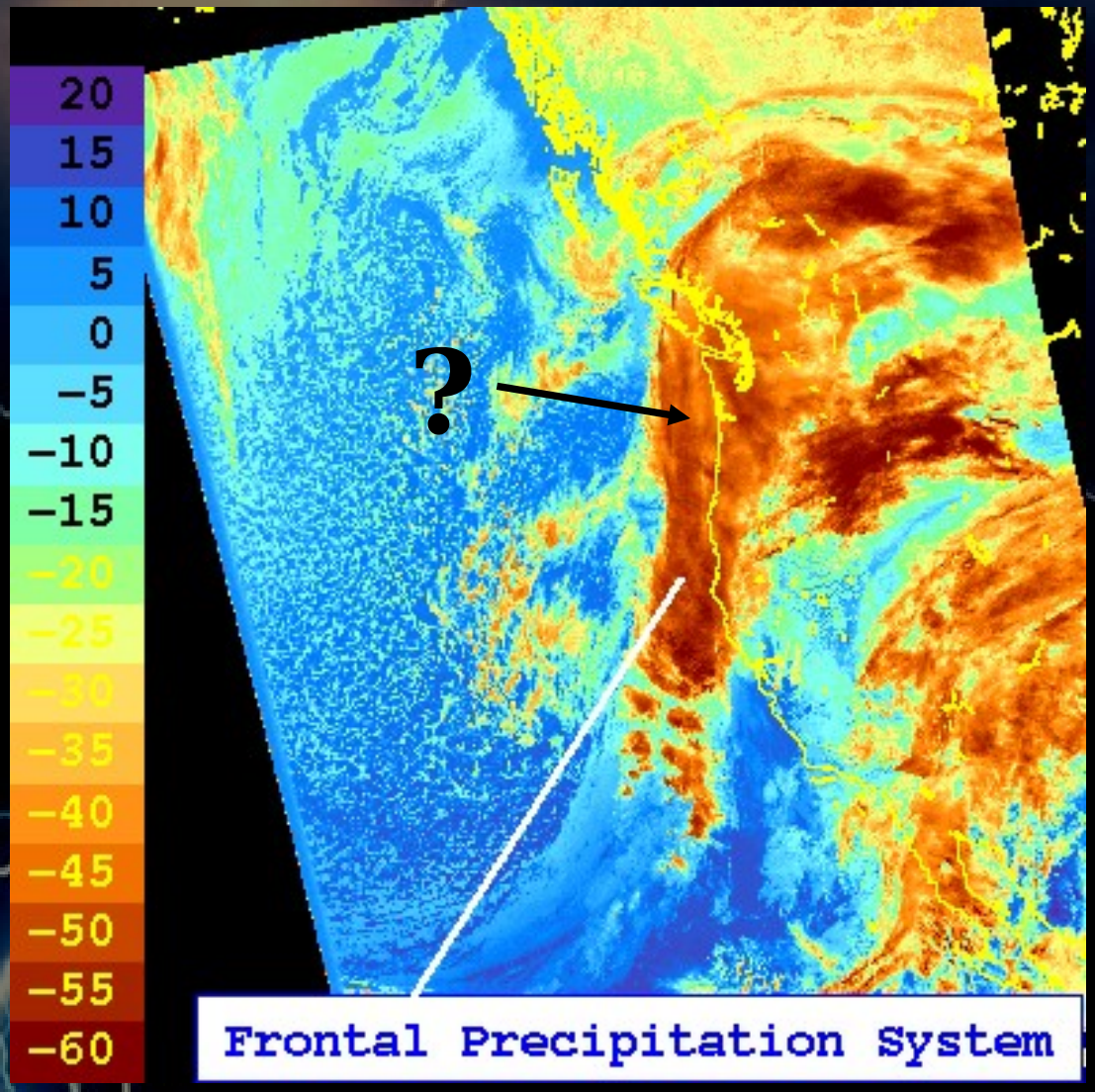
SSM/I 37V GHz


265
260
255
250
245
240
235
230
225
220
215
210
205
200
Cold, Snow-covered Terrain
Warm Land
f-11 94/02/17 01:33:36

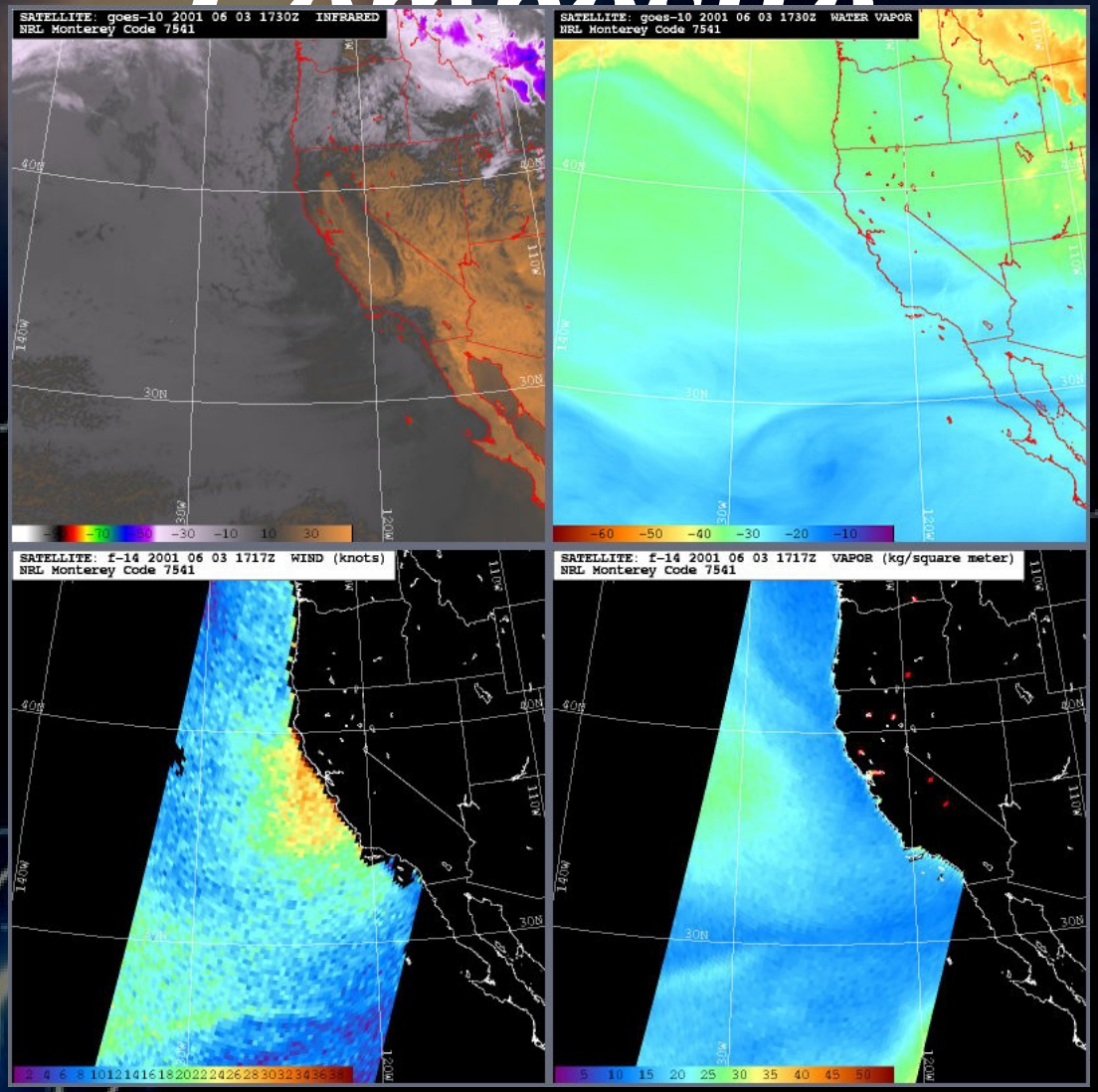
SSM/I 22V GHz


265
260
255
250
245
240
235
230
225
220
215
210
205
200
195
190
185
180
175
170
"Cold" Ocean indicates lack of clouds or moisture
"Warmer" Ocean indicates clouds and vapor
f-11 94/02/17 01:33:36

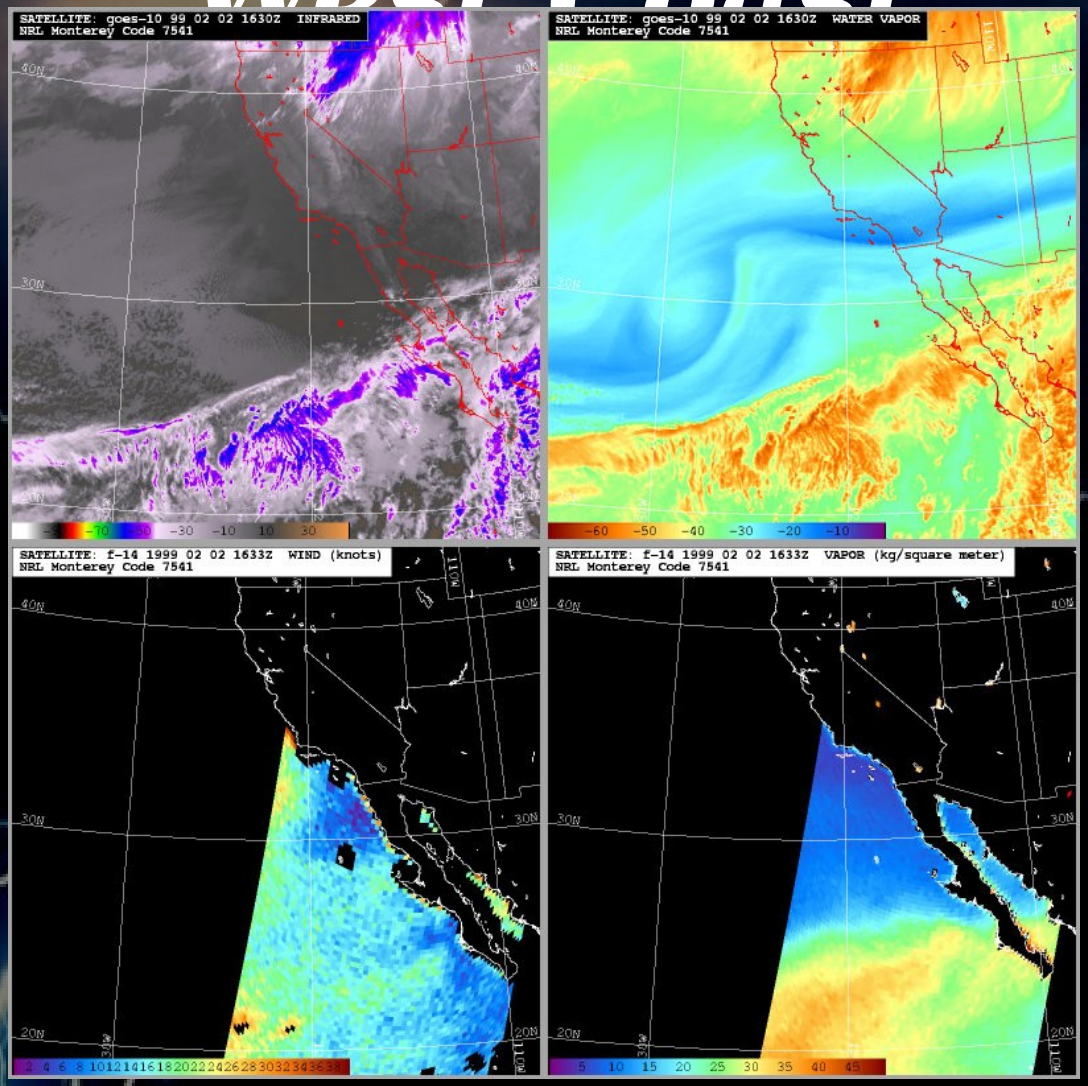
DMSP IR Image



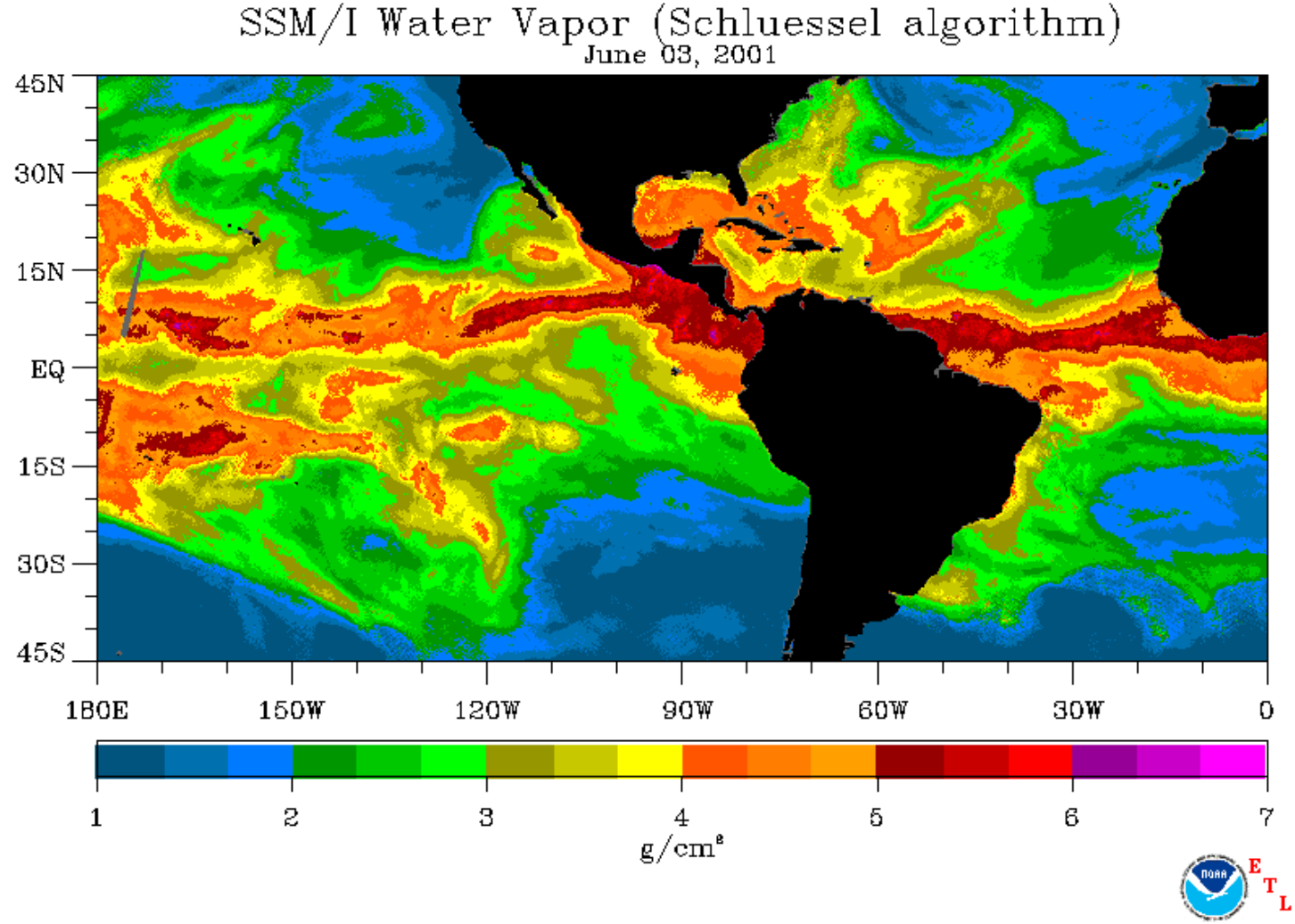
SSM/I Wind Speed Composite


SATELLITE: goes-10 2001 06 03 1730Z INFRARED
NRL Monterey Code 7541
SATELLITE: goes-10 2001 06 03 1730Z WATER VAPOR
NRL Monterey Code 7541
SATELLITE: f-14 2001 06 03 1717Z WIND (knots)
NRL Monterey Code 7541
SATELLITE: f-14 2001 06 03 1717Z VAPOR (kg/square meter)
NRL Monterey Code 7541

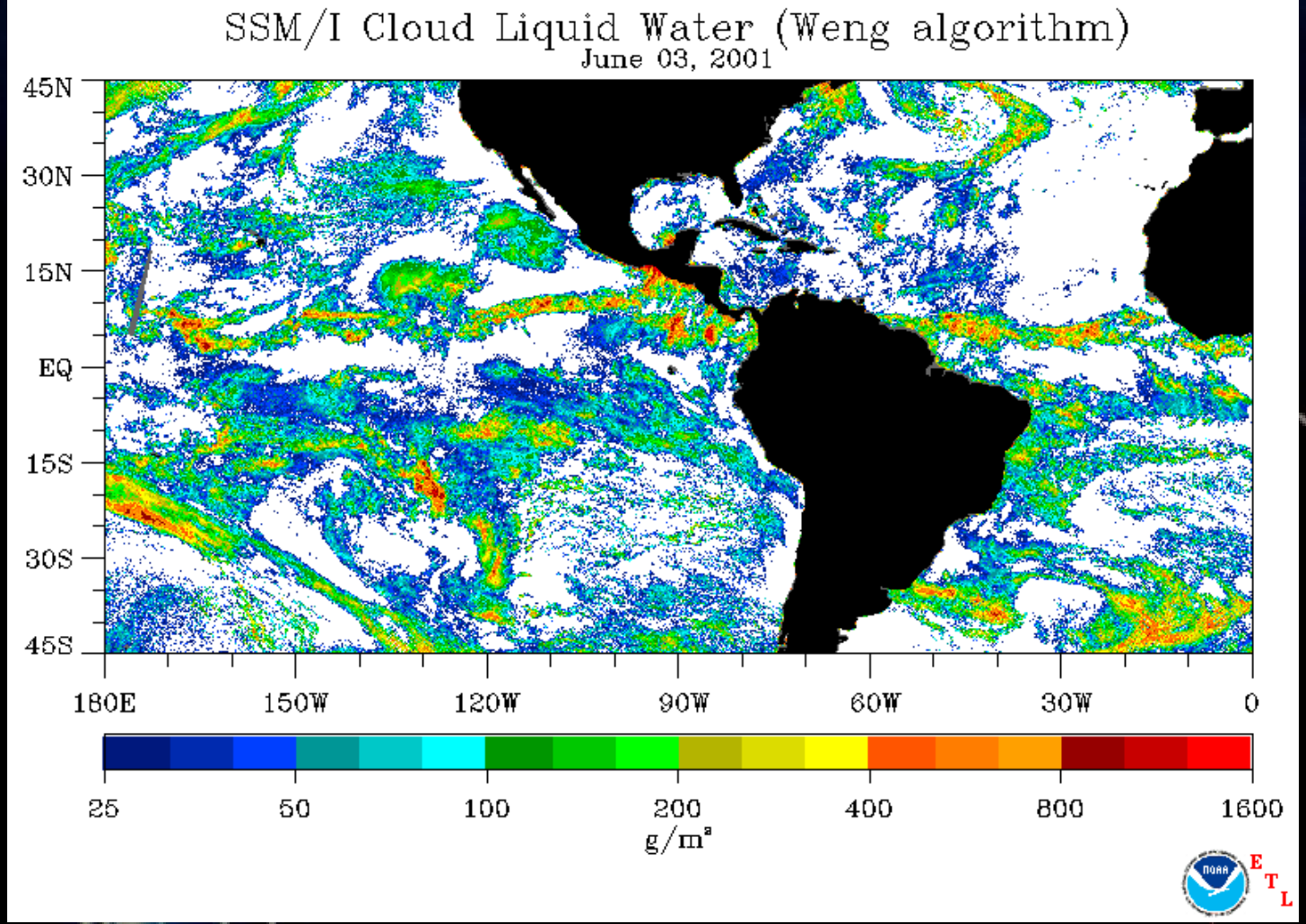
SSM/I Composite off West Coast


SATELLITE: goes-10 99 02 02 1630Z INFRARED
NRL Monterey Code 7541
SATELLITE: goes-10 99 02 02 1630Z WATER VAPOR
NRL Monterey Code 7541
SATELLITE: f-14 1999 02 02 1633Z WIND (knots)
NRL Monterey Code 7541
SATELLITE: f-14 1999 02 02 1633Z VAPOR (kg/square meter)
NRL Monterey Code 7541

SSM/I Total Precipitable Water

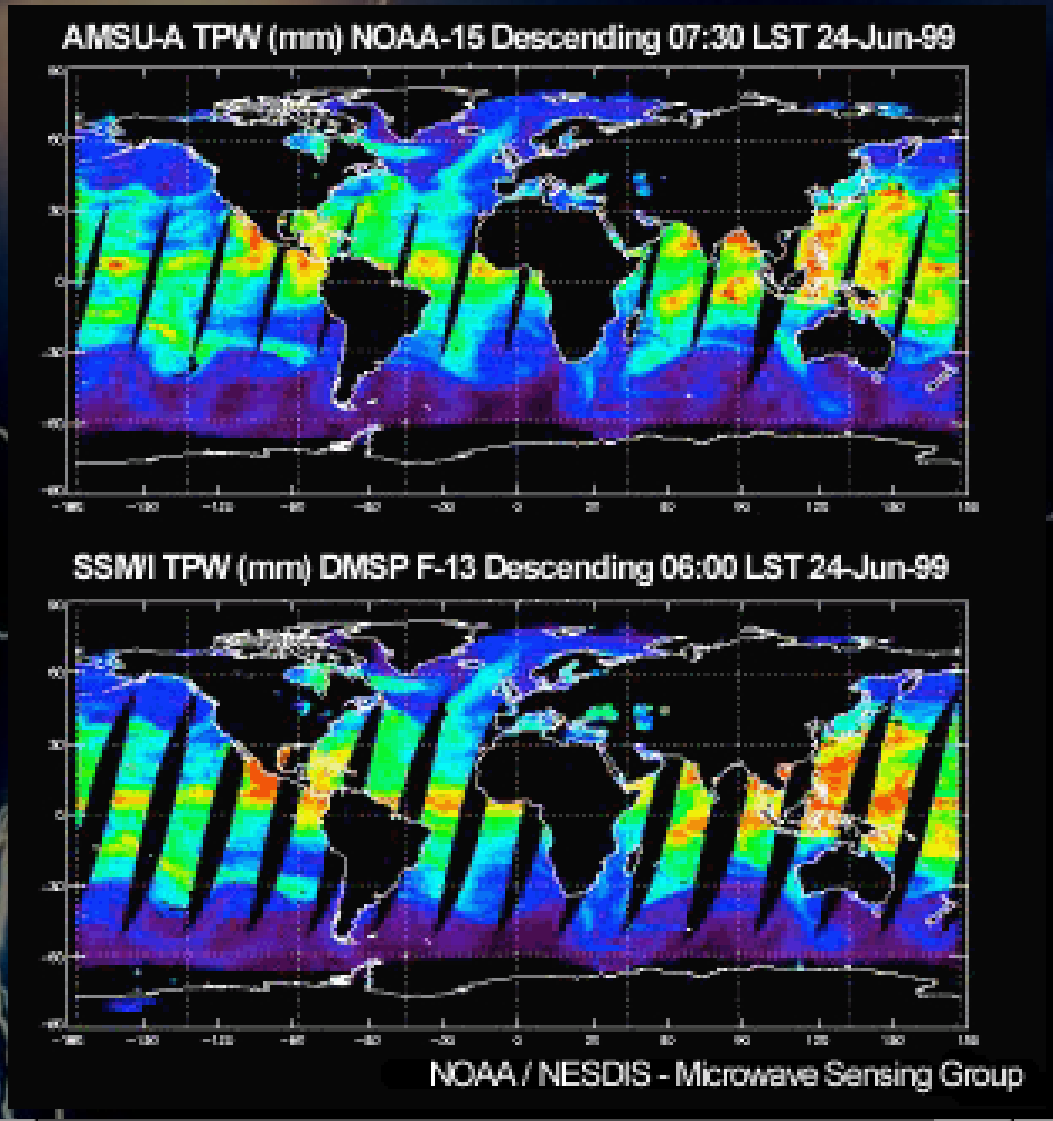


SSM/I Cloud Liquid Water



NOAA (AMSU) Coverage

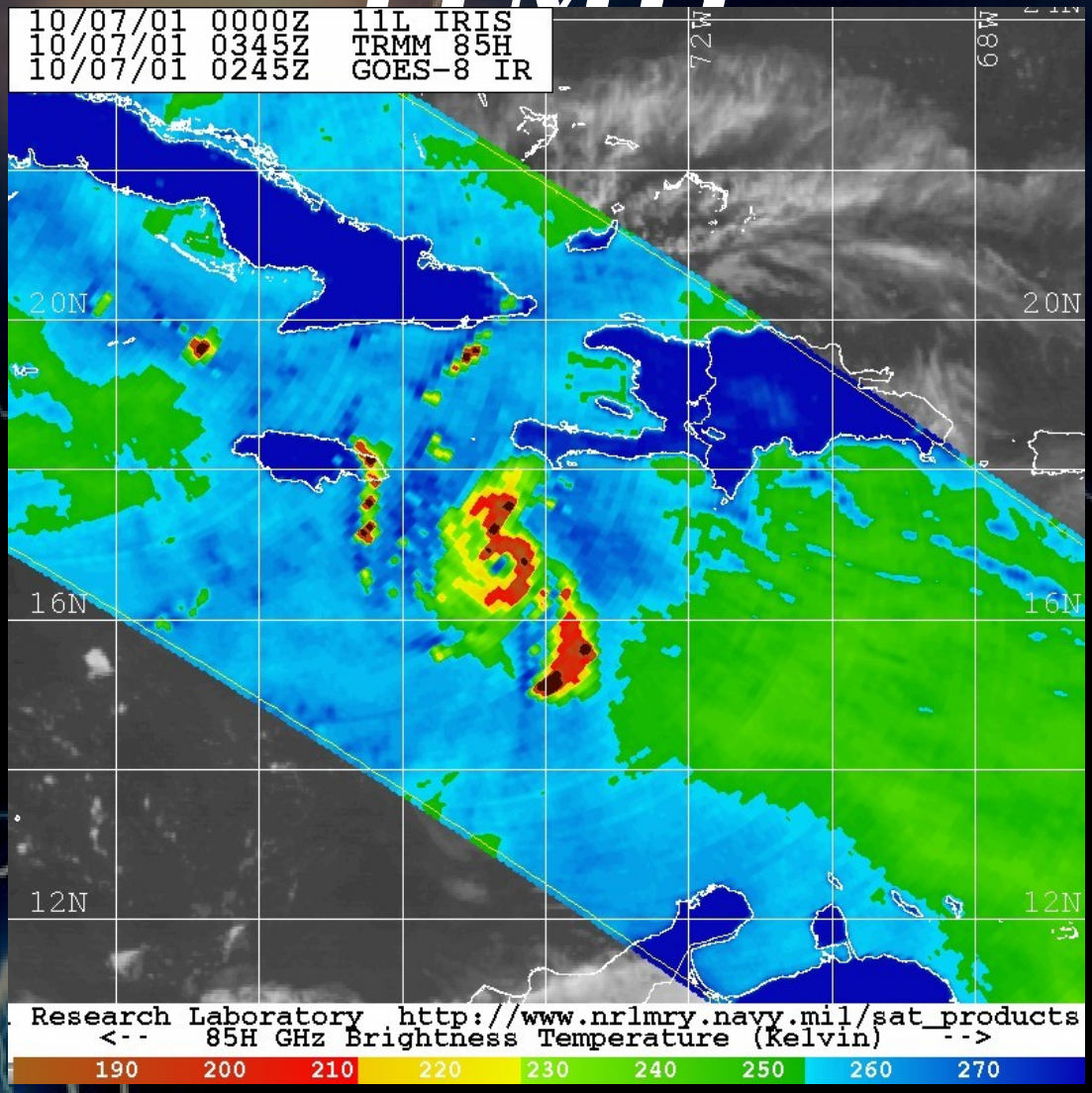
AMSU vs. SSM/I


AMSU-A TPW (mm) NOAA-15 Descending 07:30 LST 24-Jun-99
SSM/I TPW (mm) DMSP F-13 Descending 06:00 LST 24-Jun-99
NOAA / NESDIS - Microwave Sensing Group

Tropical Rainfall Measuring Mission (TRMM)

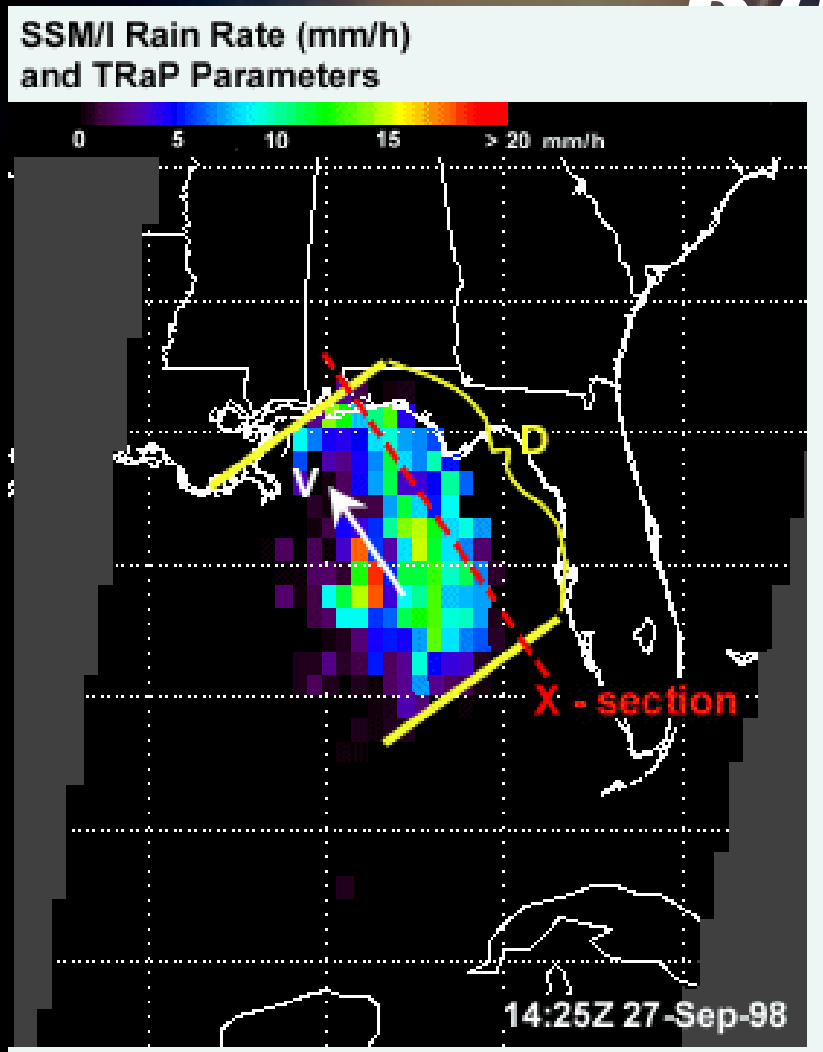
- Precipitation Radar (PR)
- TRMM Microwave Imager (TMI)
- Visible and Infrared Scanner (VIRS)
- Cloud and Earth Radiant Energy System (CERES)
- Lightning Imaging Sensor (LIS)

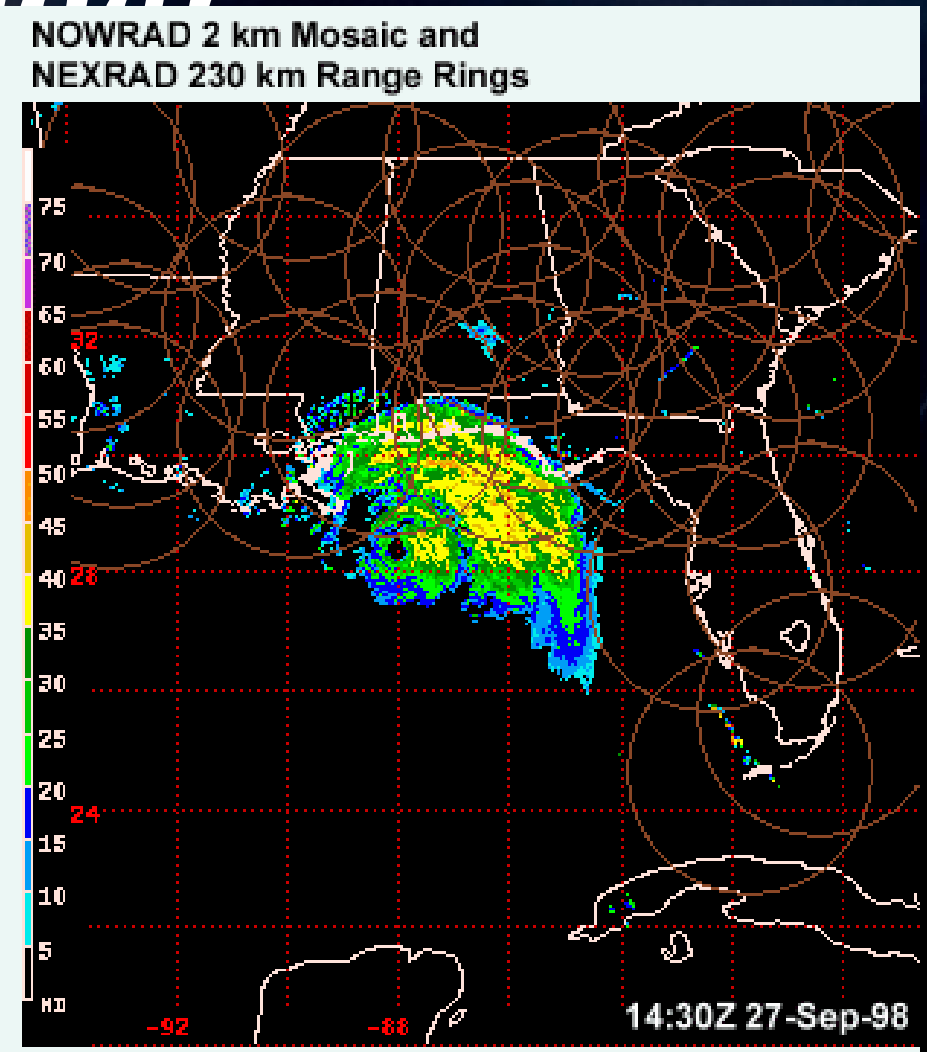
TRMM Microwave Imager (TMI)



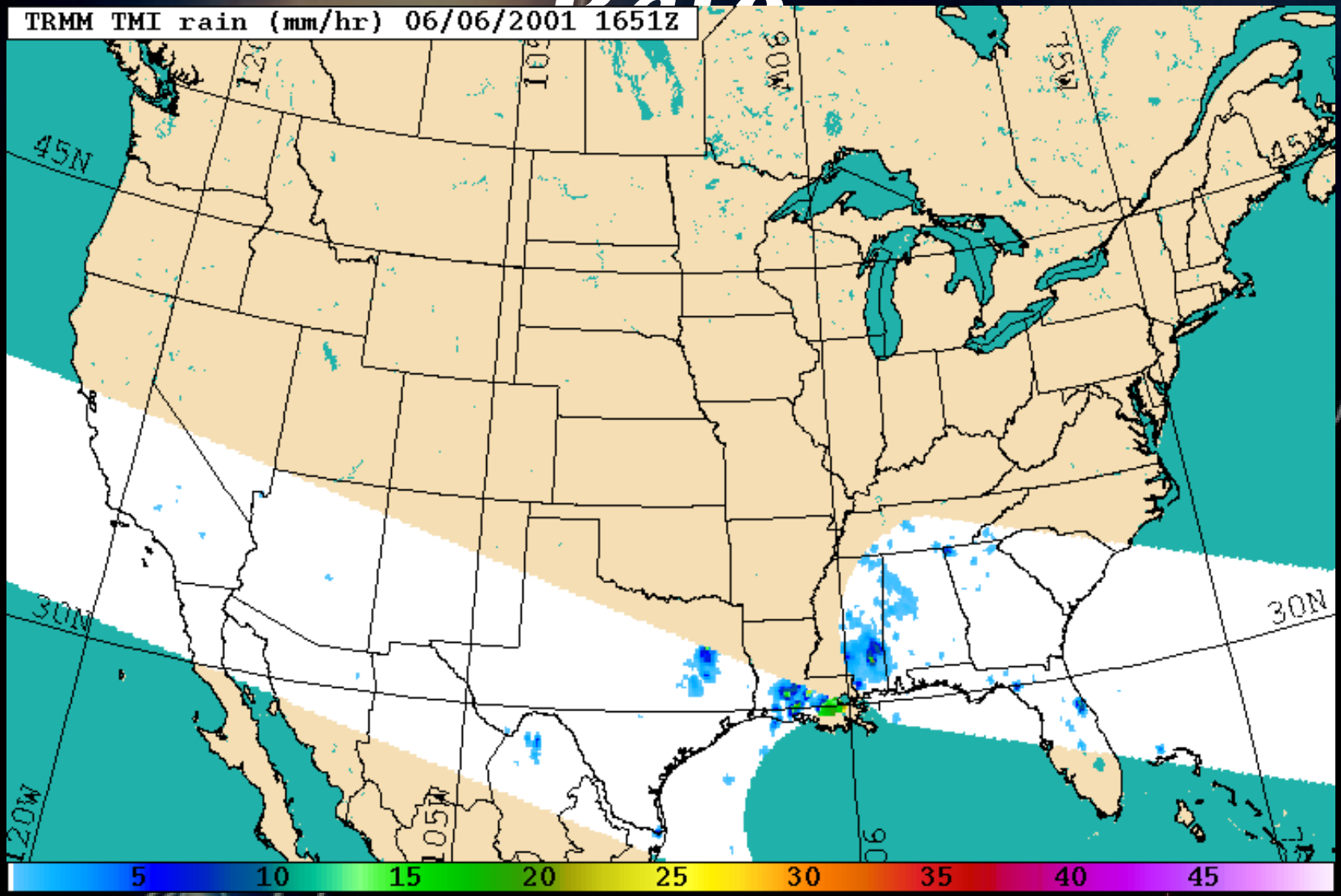
Geostationary/Microwave Rain Rate

Microwave Rainfall vs. Radar



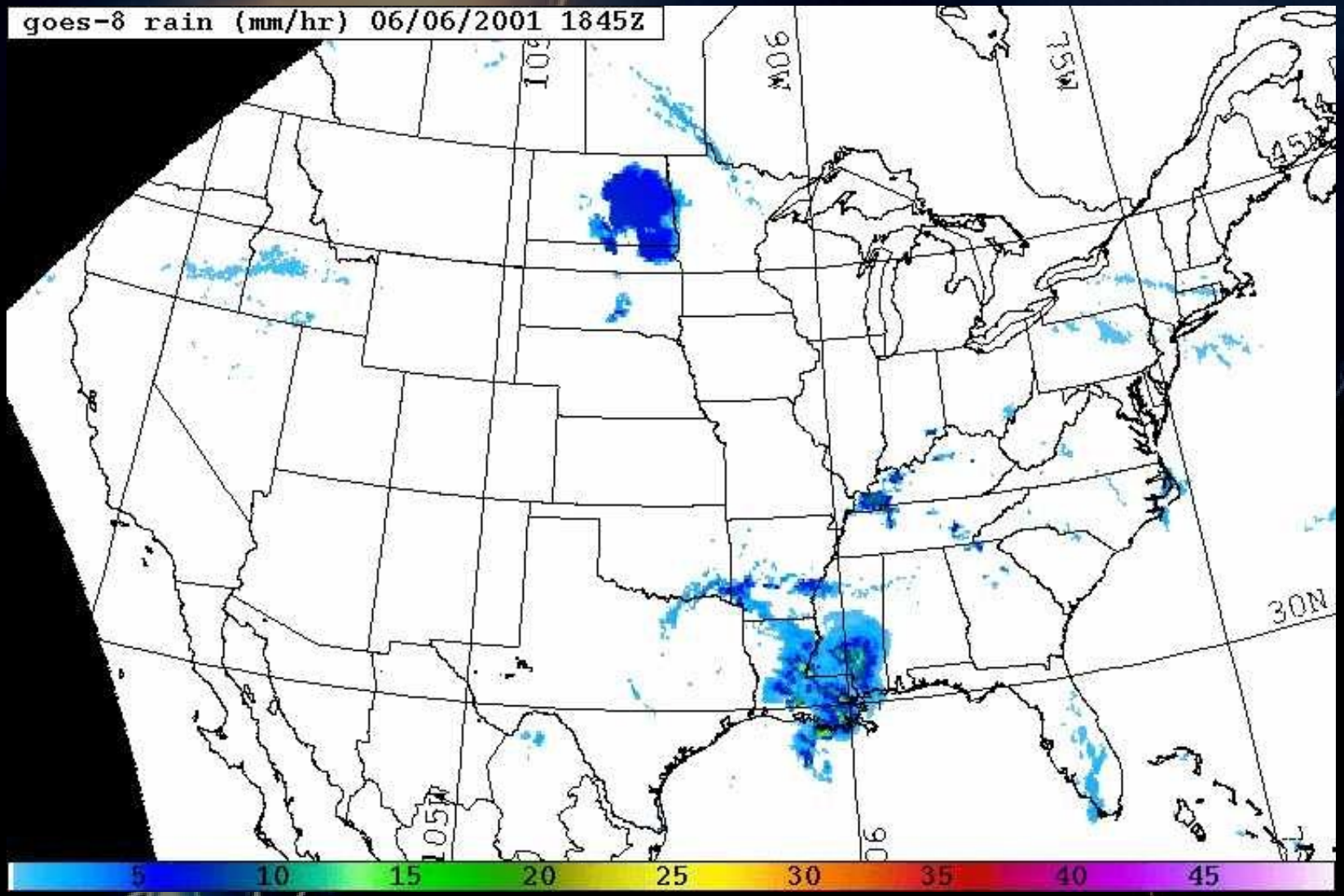


TRMM/GOES Rainfall Rate

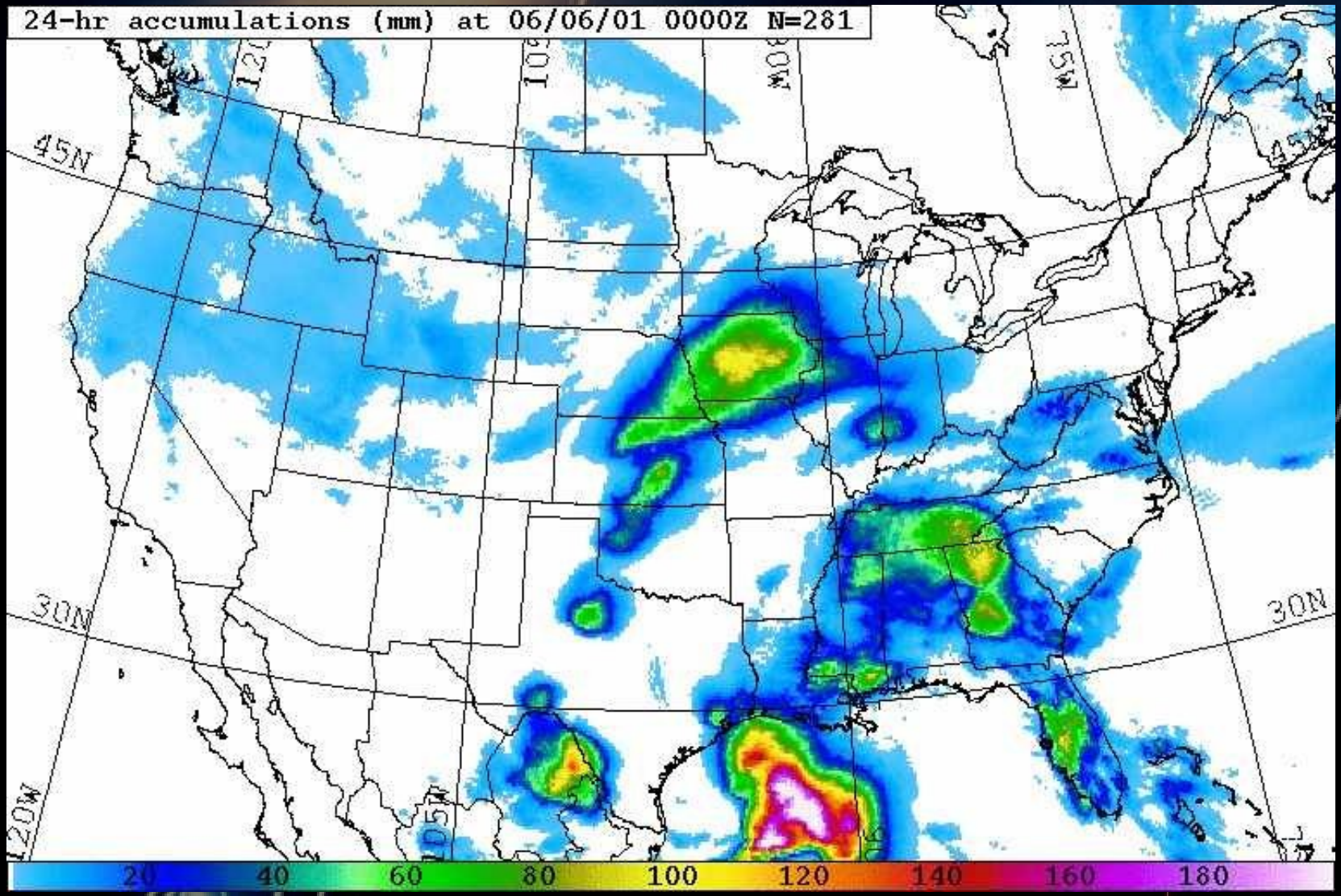


Corresponding GOES IR

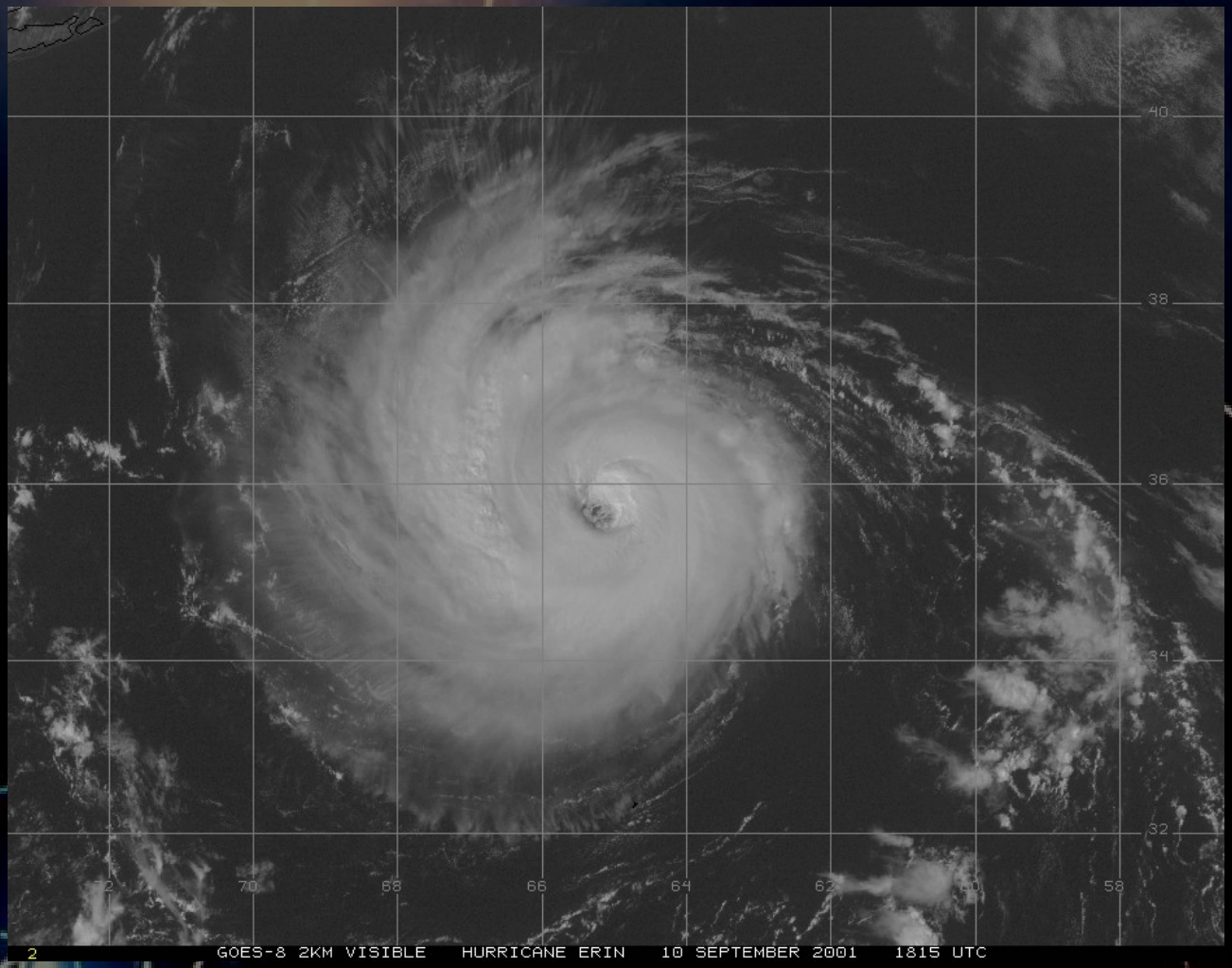
3 Hour Accumulation



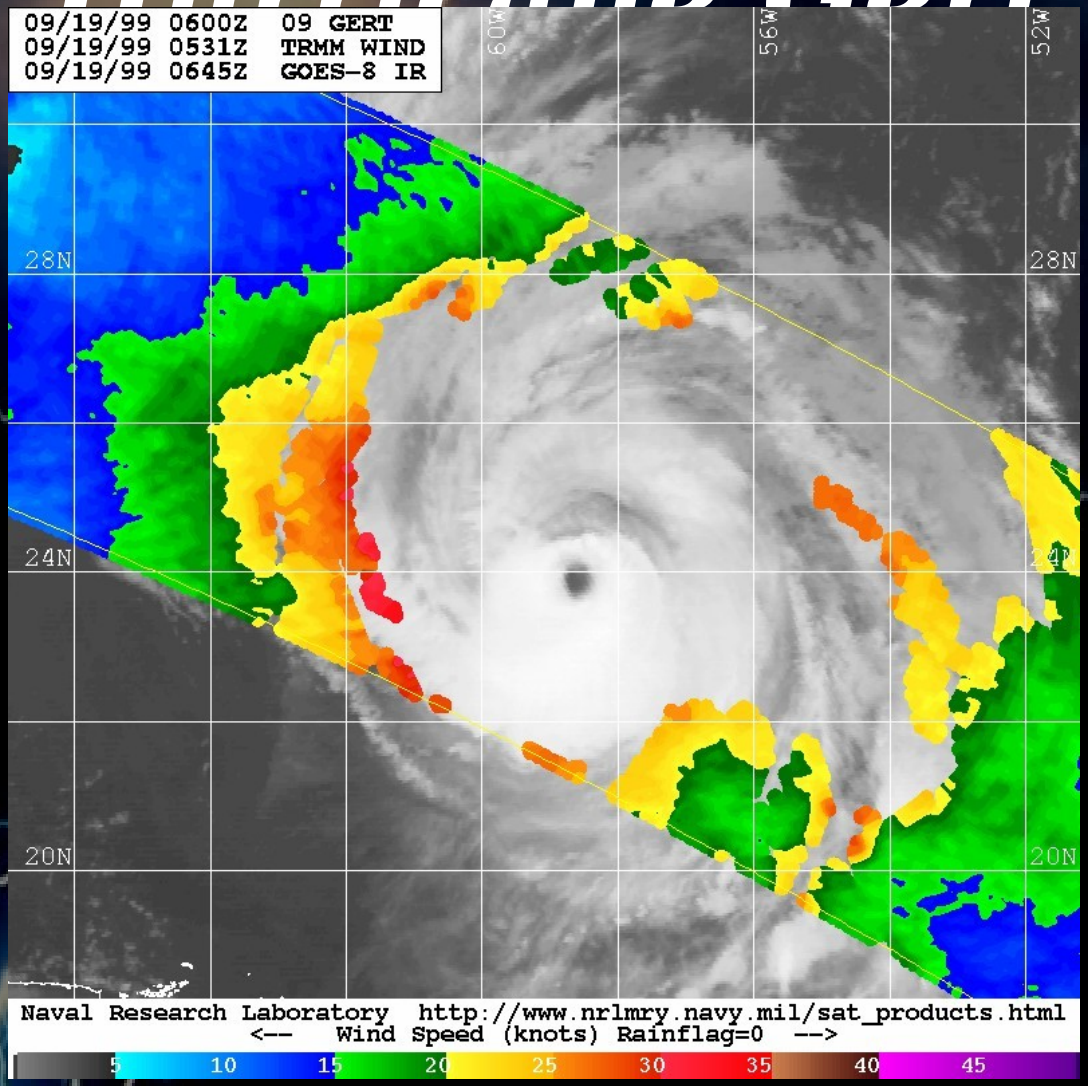
24 Hour Accumulation



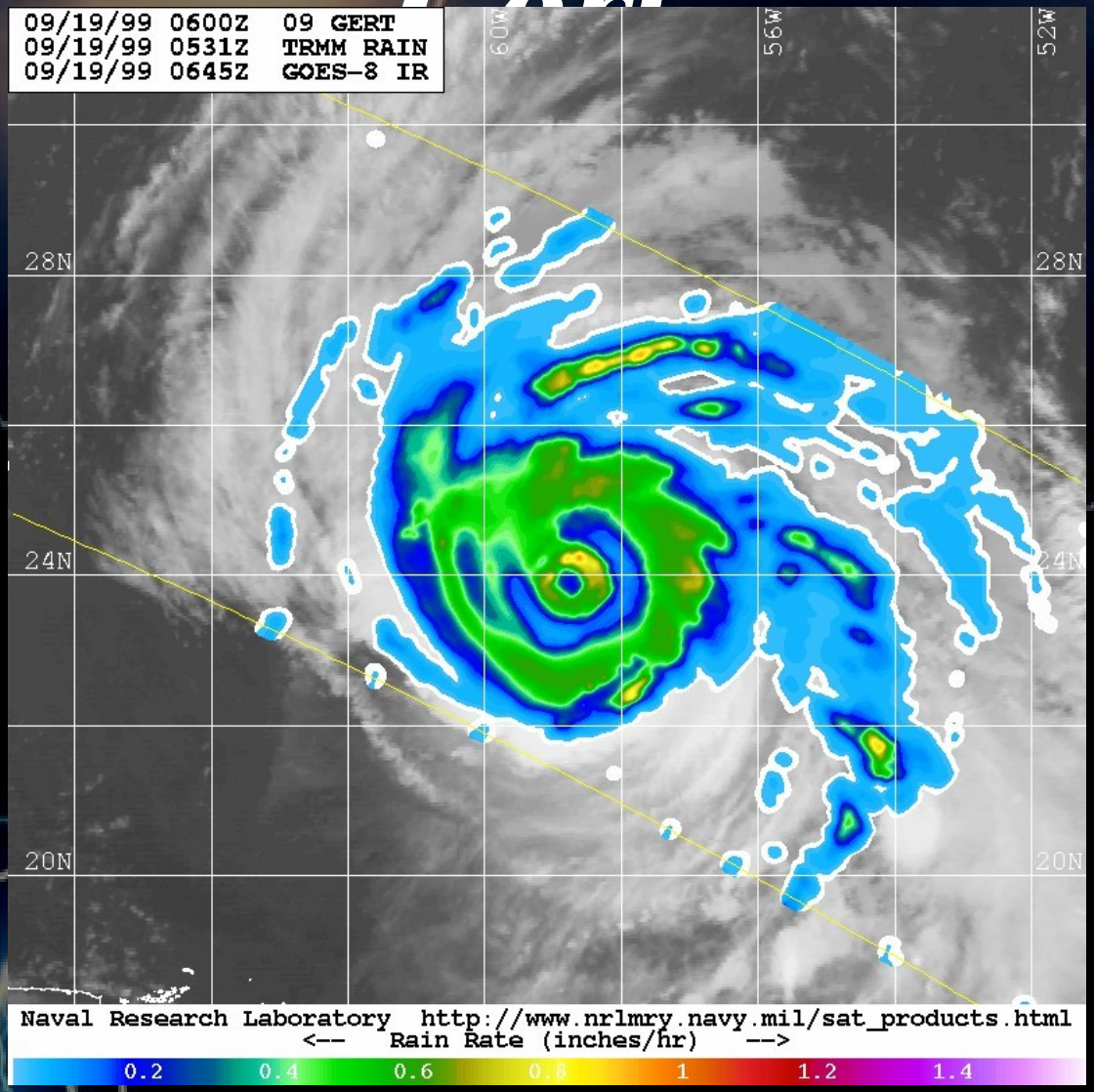
Tropical Cyclones



TMI Wind Speed over Hurricane Gert

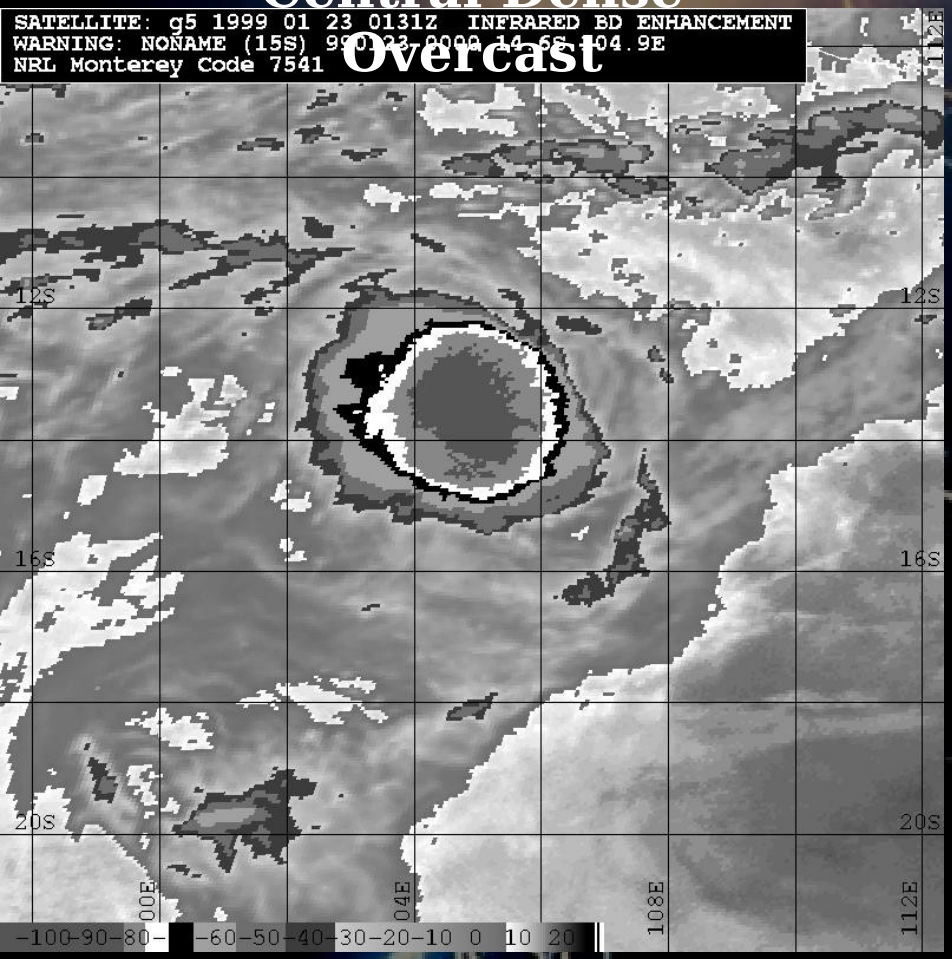


TMI Rain Rate over Gert



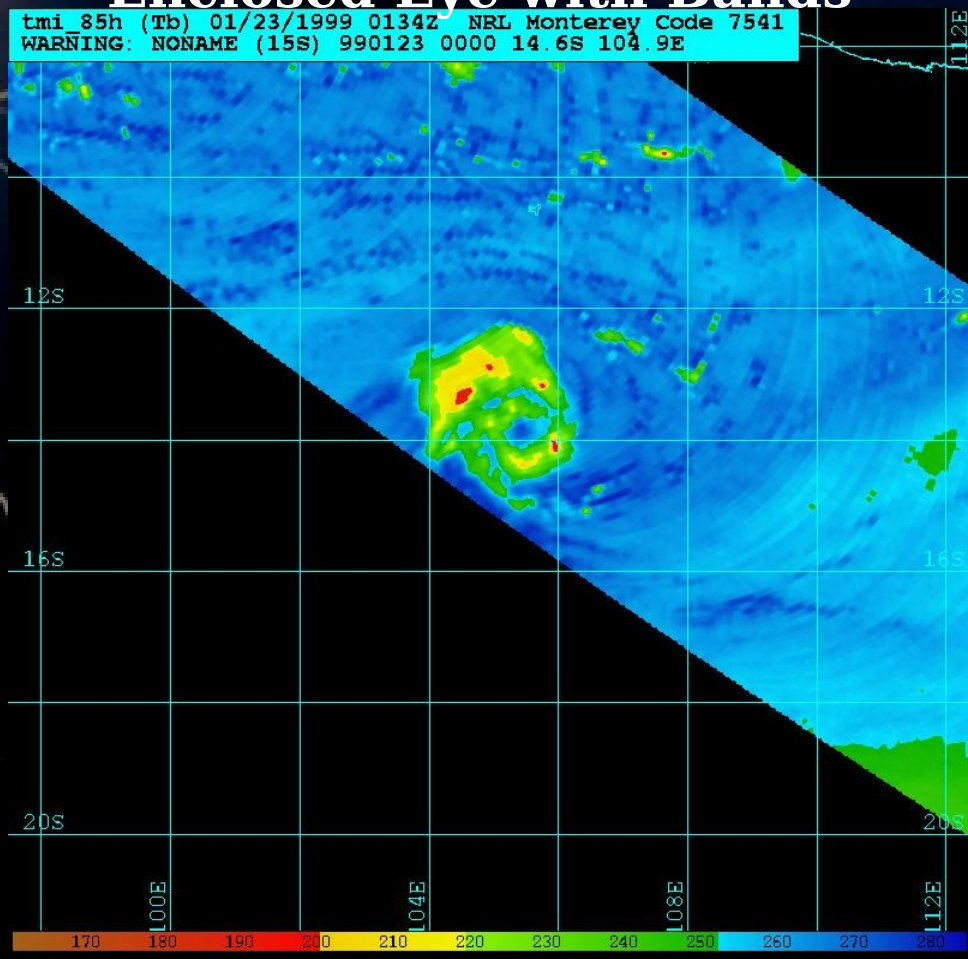
TRMM Microwave Imagery Relocated Tropical Cyclone Position - JTWC

Central Dense Overcast



Dvorak IR Enhanced GMS-5 Image

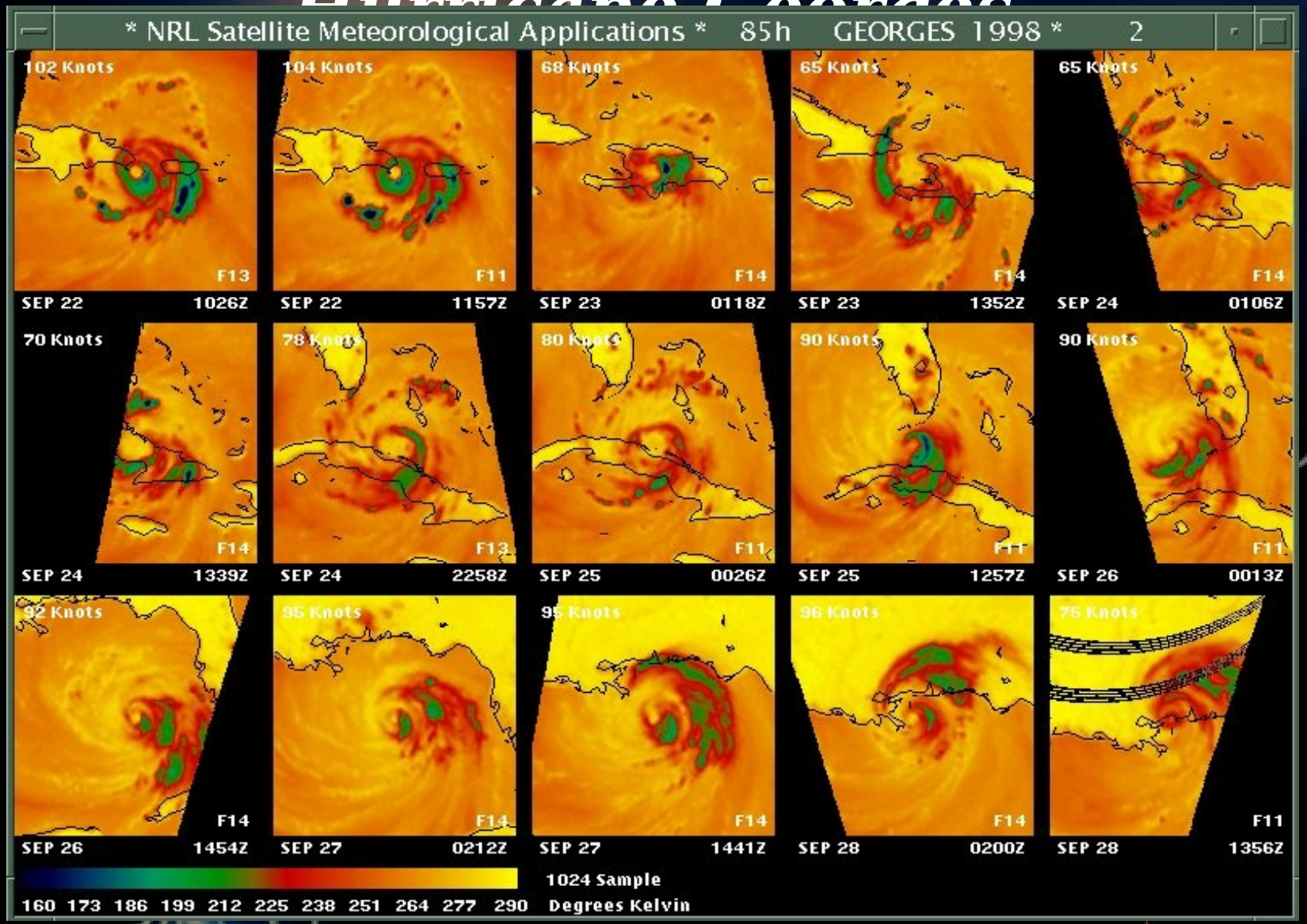
Enclosed Eye with Bands



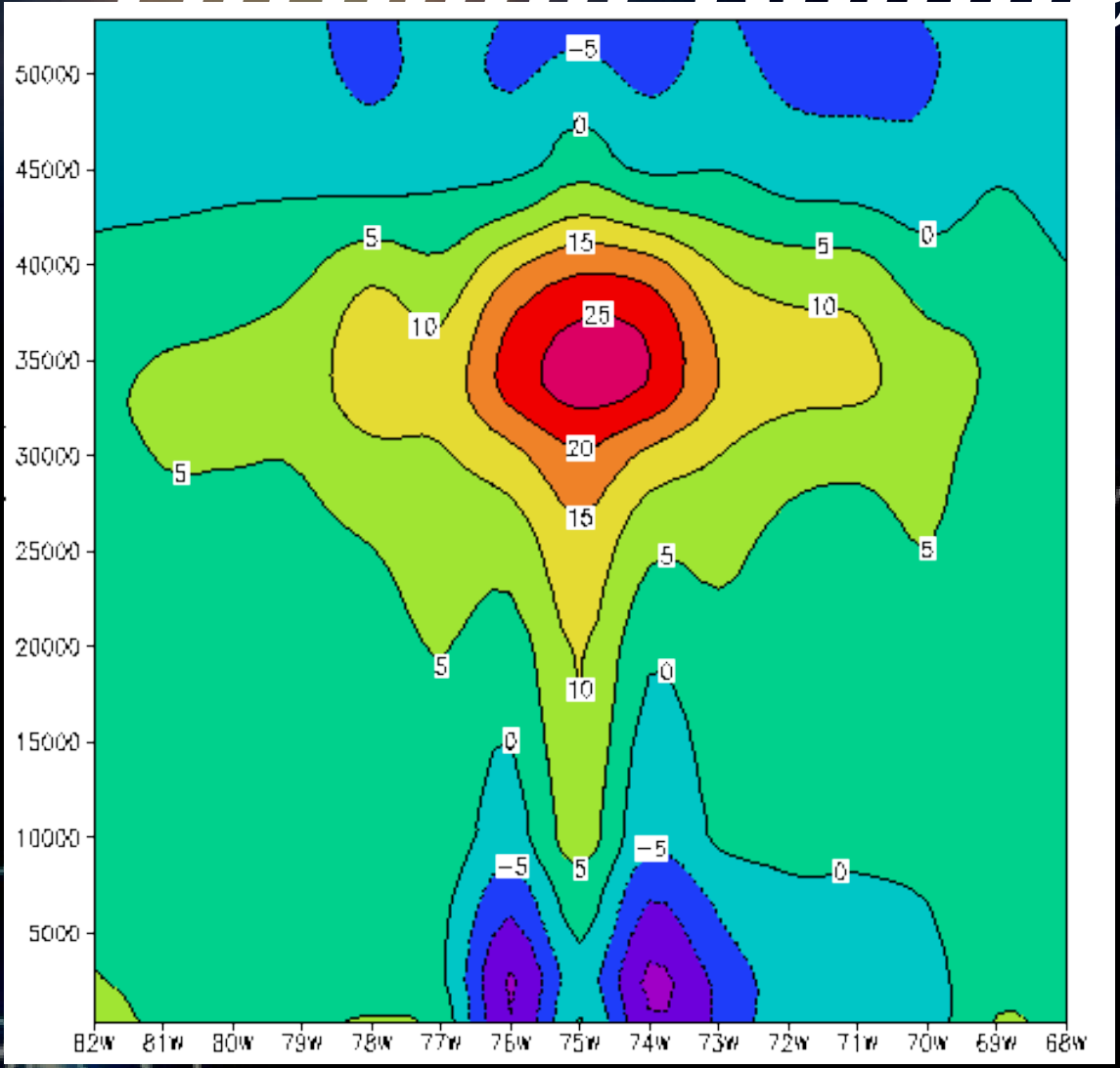
TMI 85 GHz Image: 2 minutes after GMS-5 Image

TRMM data courtesy of NASA/GSFC

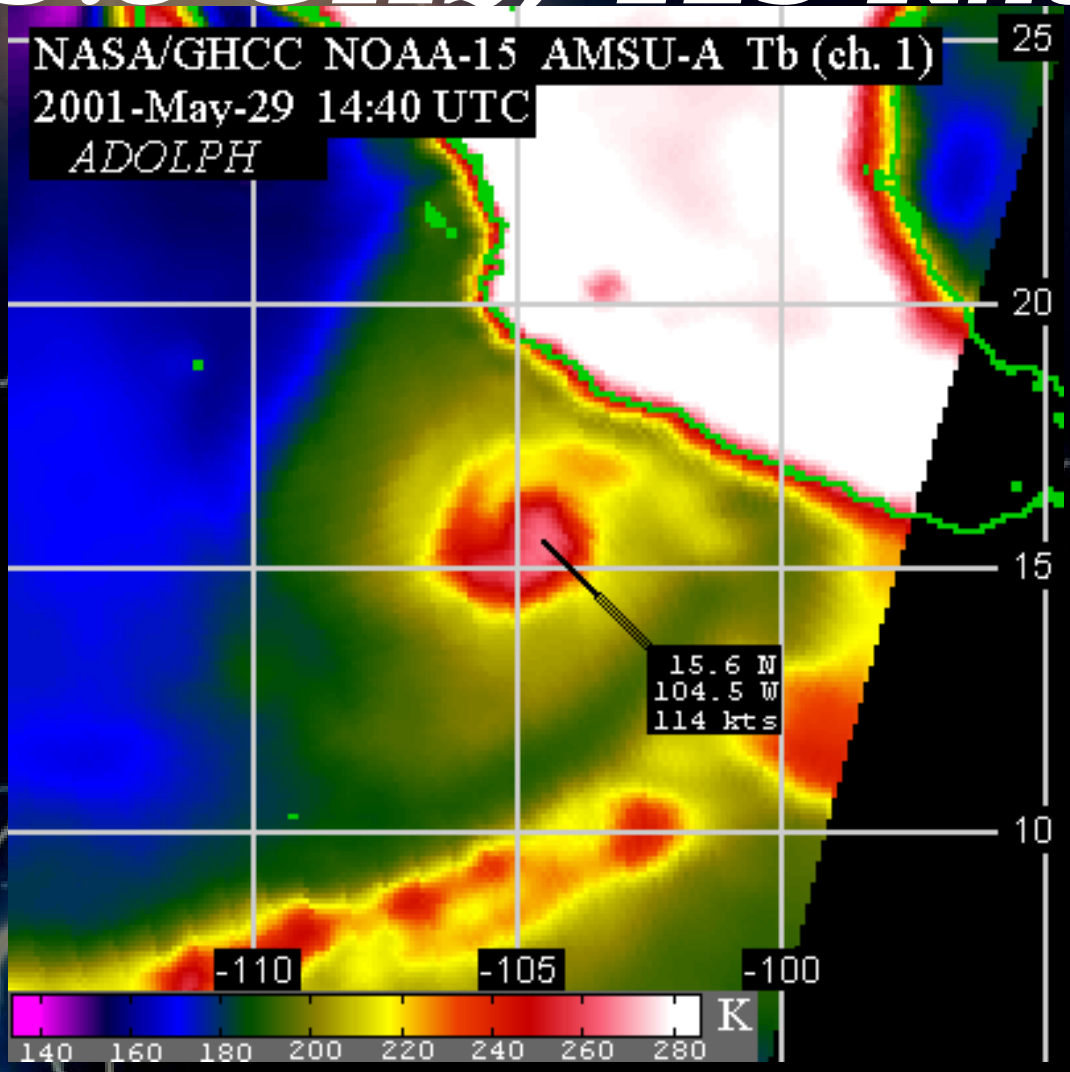
Time Series of SSM/I 85 GHz for Hurricane Georges



AMSU Cross Section Through Bonnie



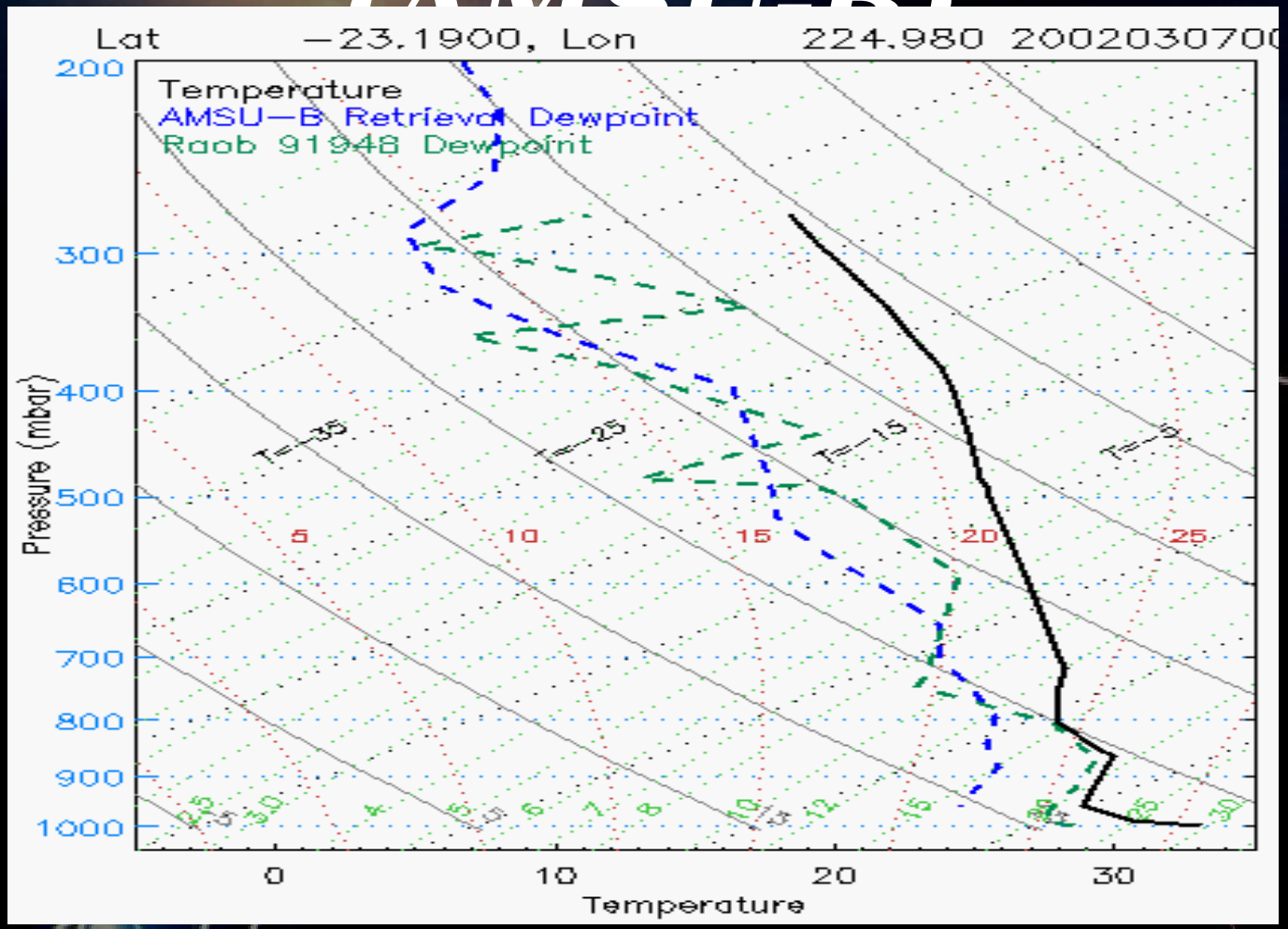
AMSU-A Channel 1 (23.8 GHz) 123 Knots



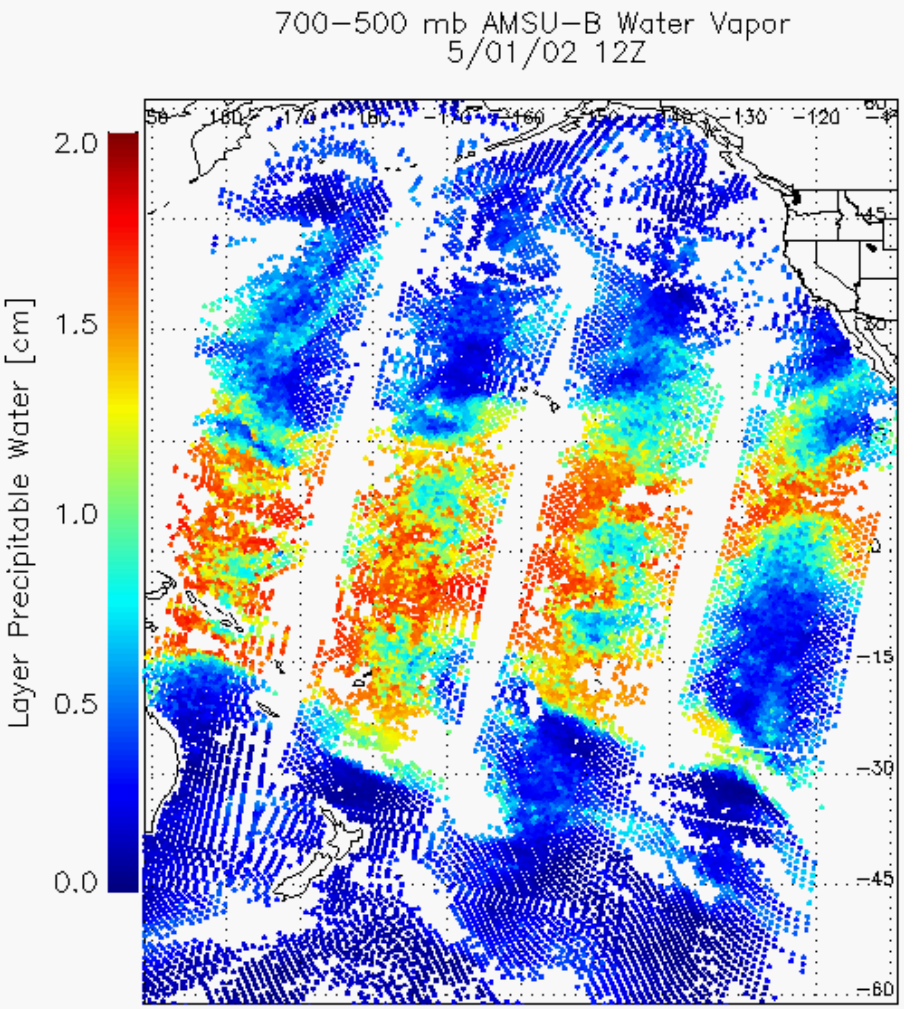
Differences Between Microwave Sounders and Imagers

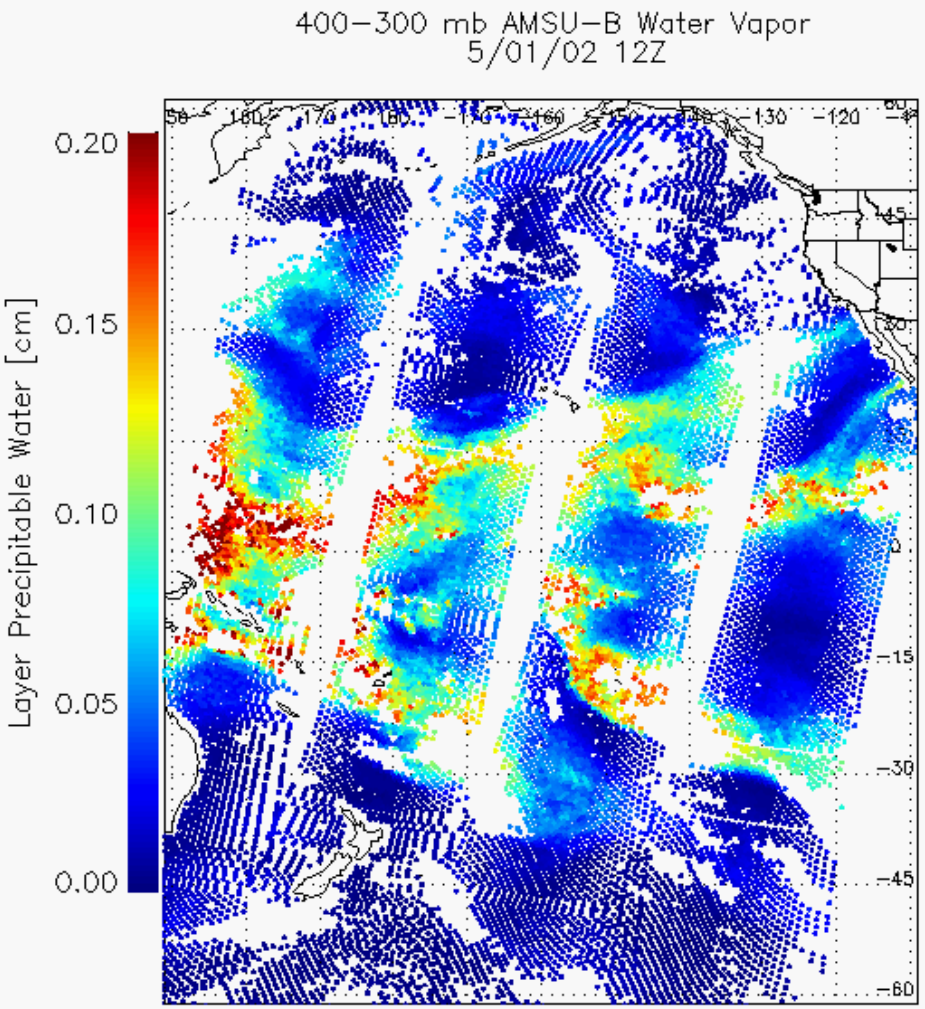
- Sounder information gives us vertical profiles of temperature and moisture (3-dimensional).
- Imagers give us 2-dimensional products and images.
- Increasingly, there is little difference between sounders and imagers.
- Special Sensor microwave Imager/Sounder (SSM/IS) recognizes that sounder/imager applications can reside on one instrument (Coming in late 2002/2003.

Passive Microwave Sounder Retrievals (AMSU-B)



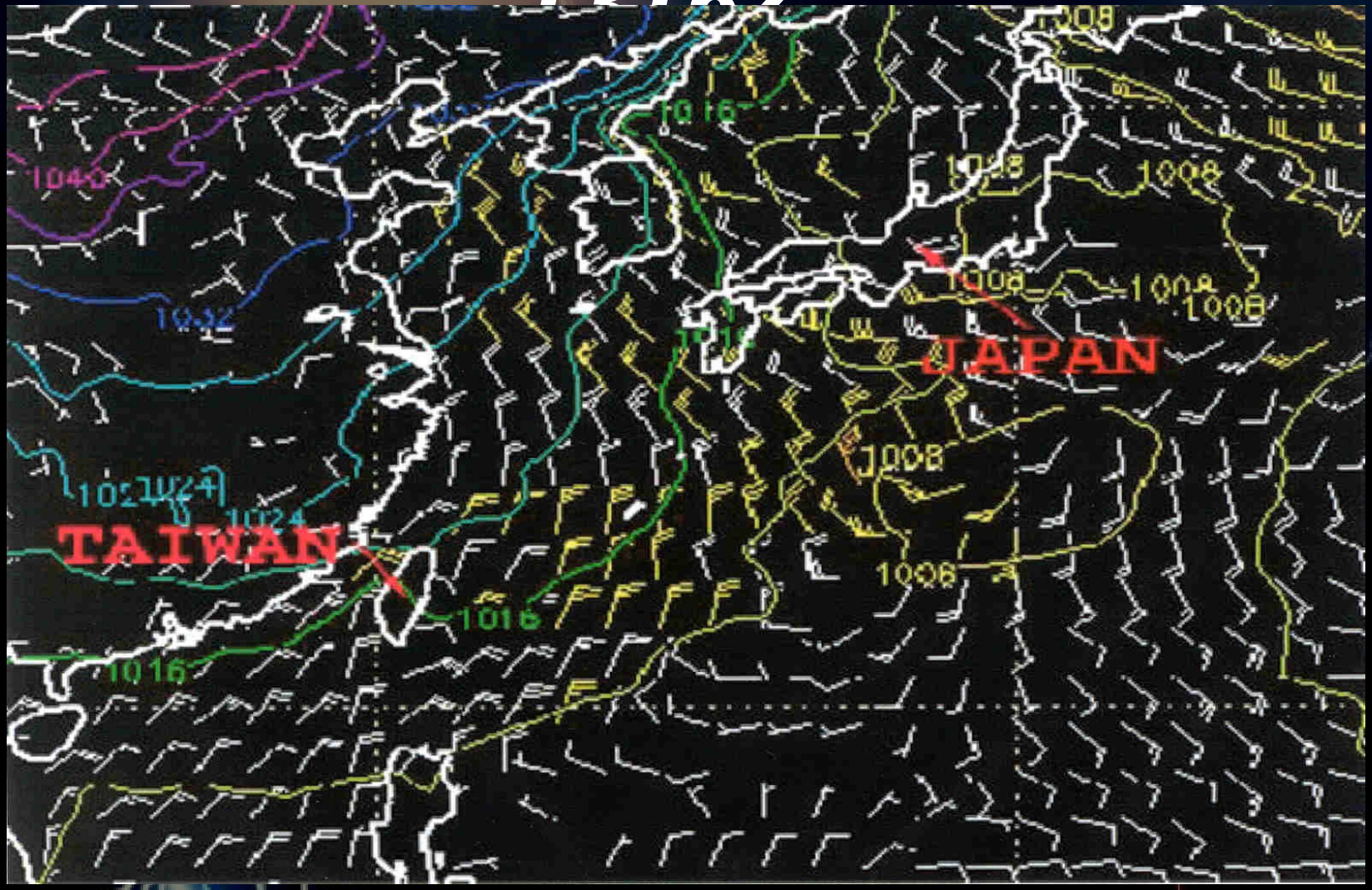
Layer Integrated Water Vapor Retrieved from AMSU-B Microwave Radiometer



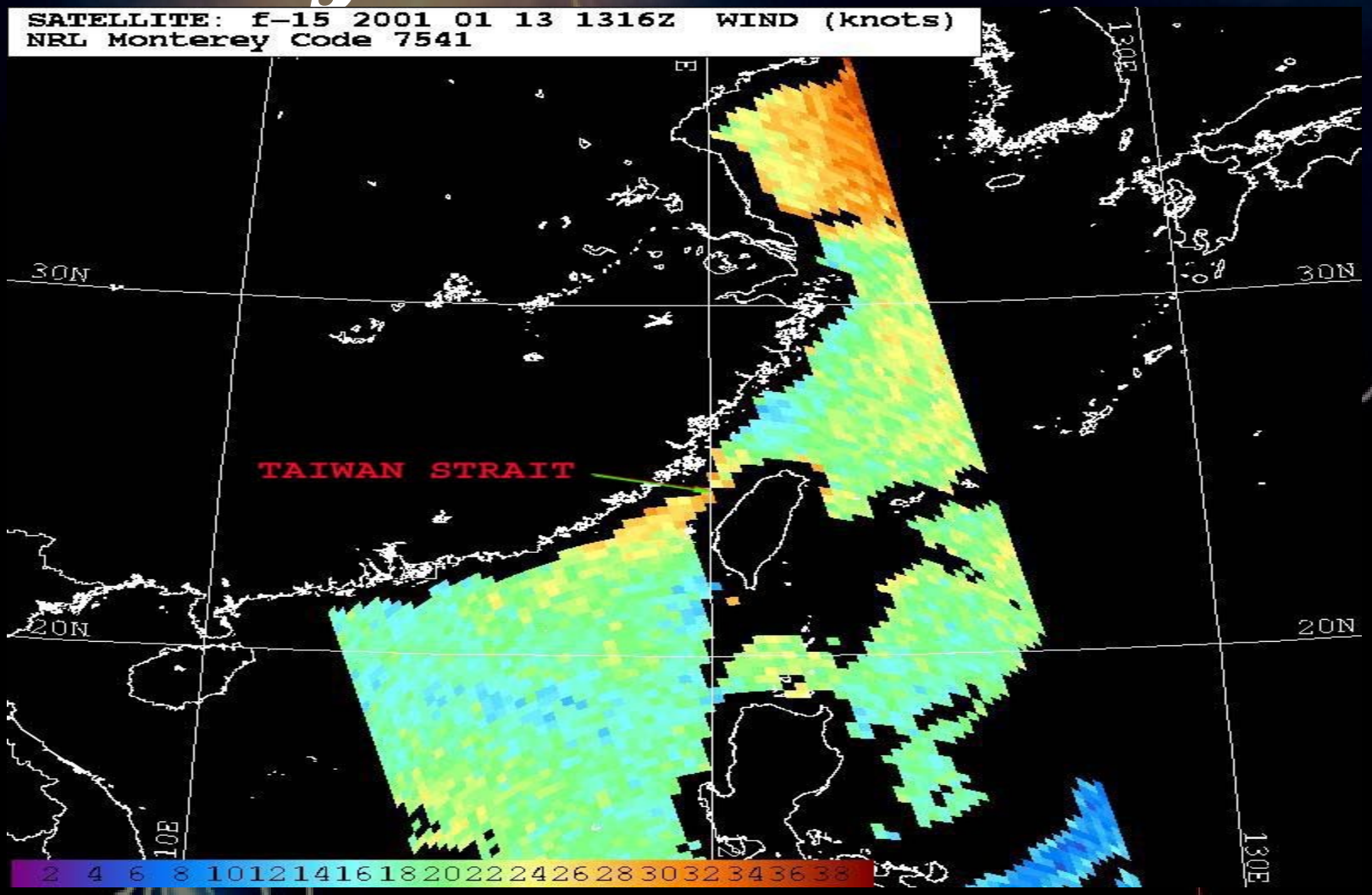


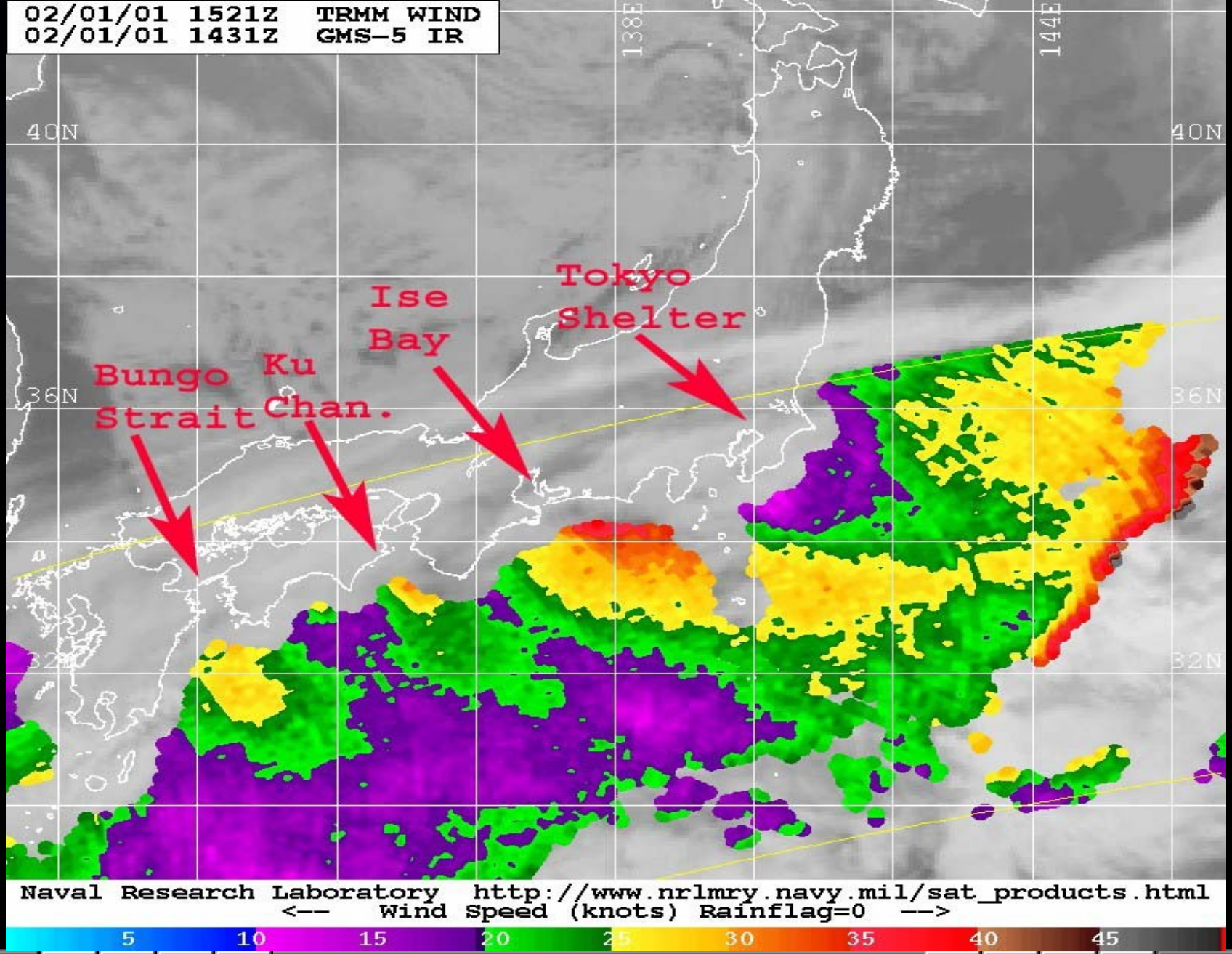
Winds

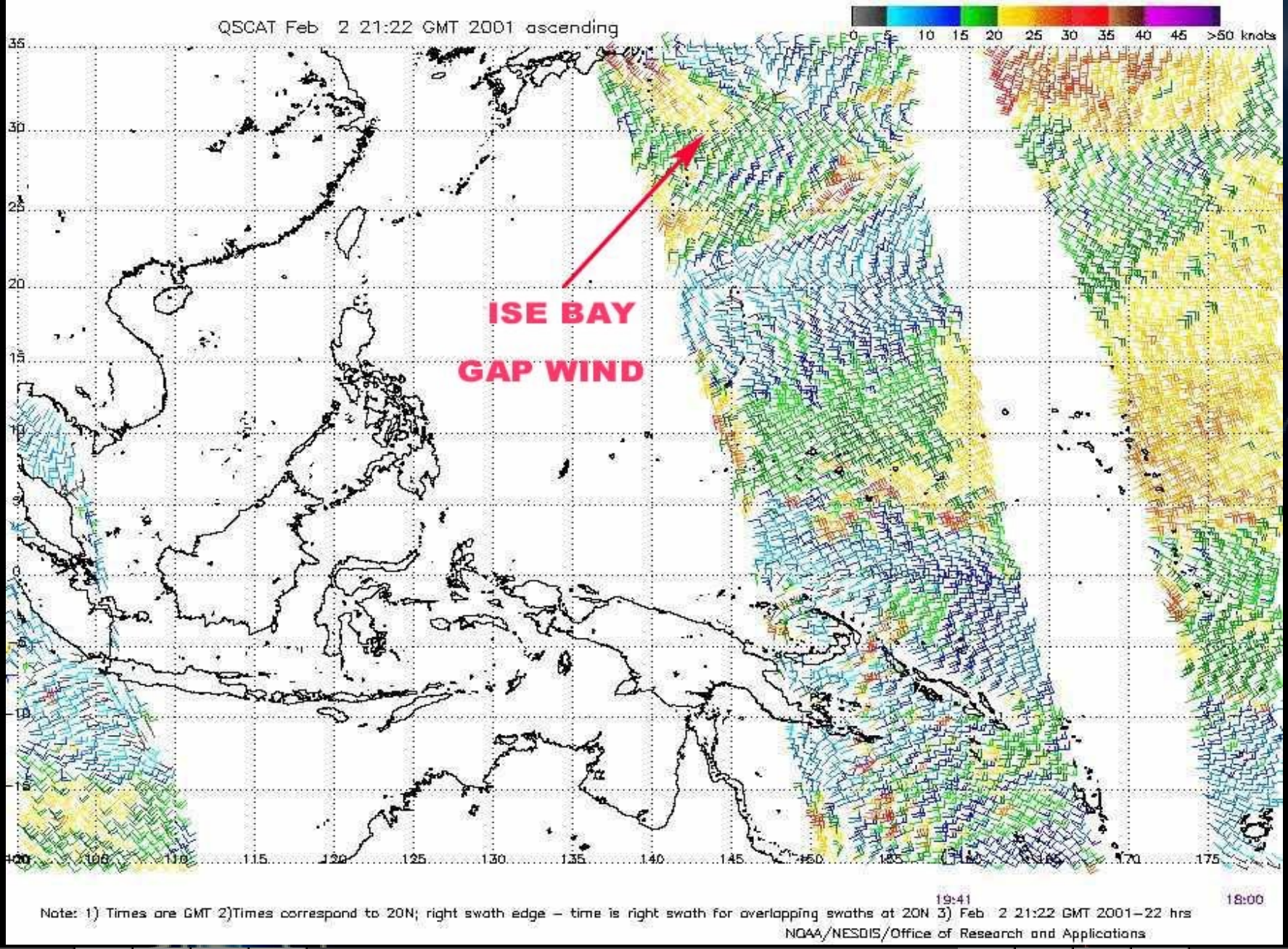
COAMPS 27 km tau 0 SLP and 10 m SFC Wind Forecast, 13 Jan 2001 1316Z

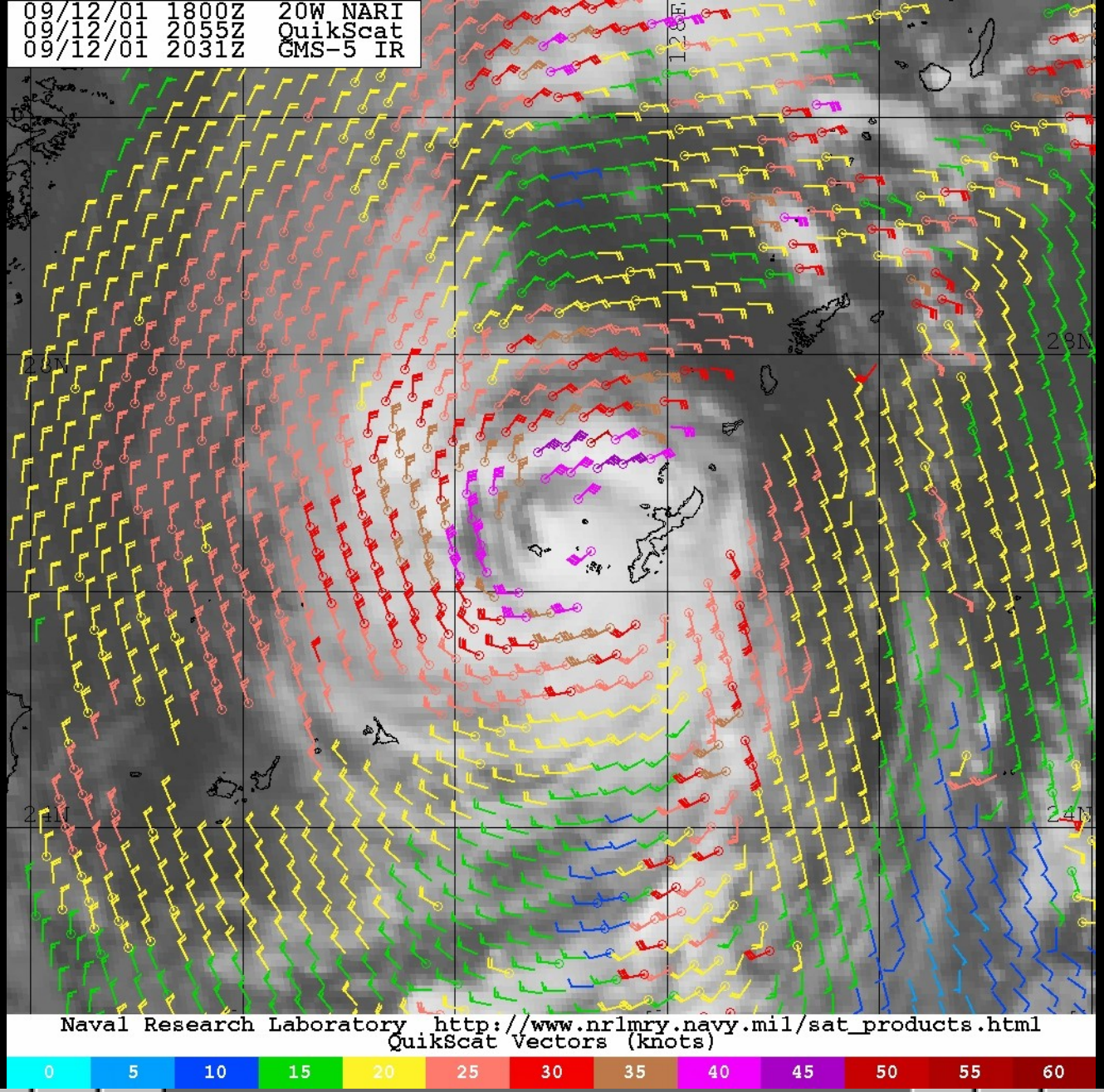


F-14 SSM/I Winds (kt)
13 Jan 2001 1316z

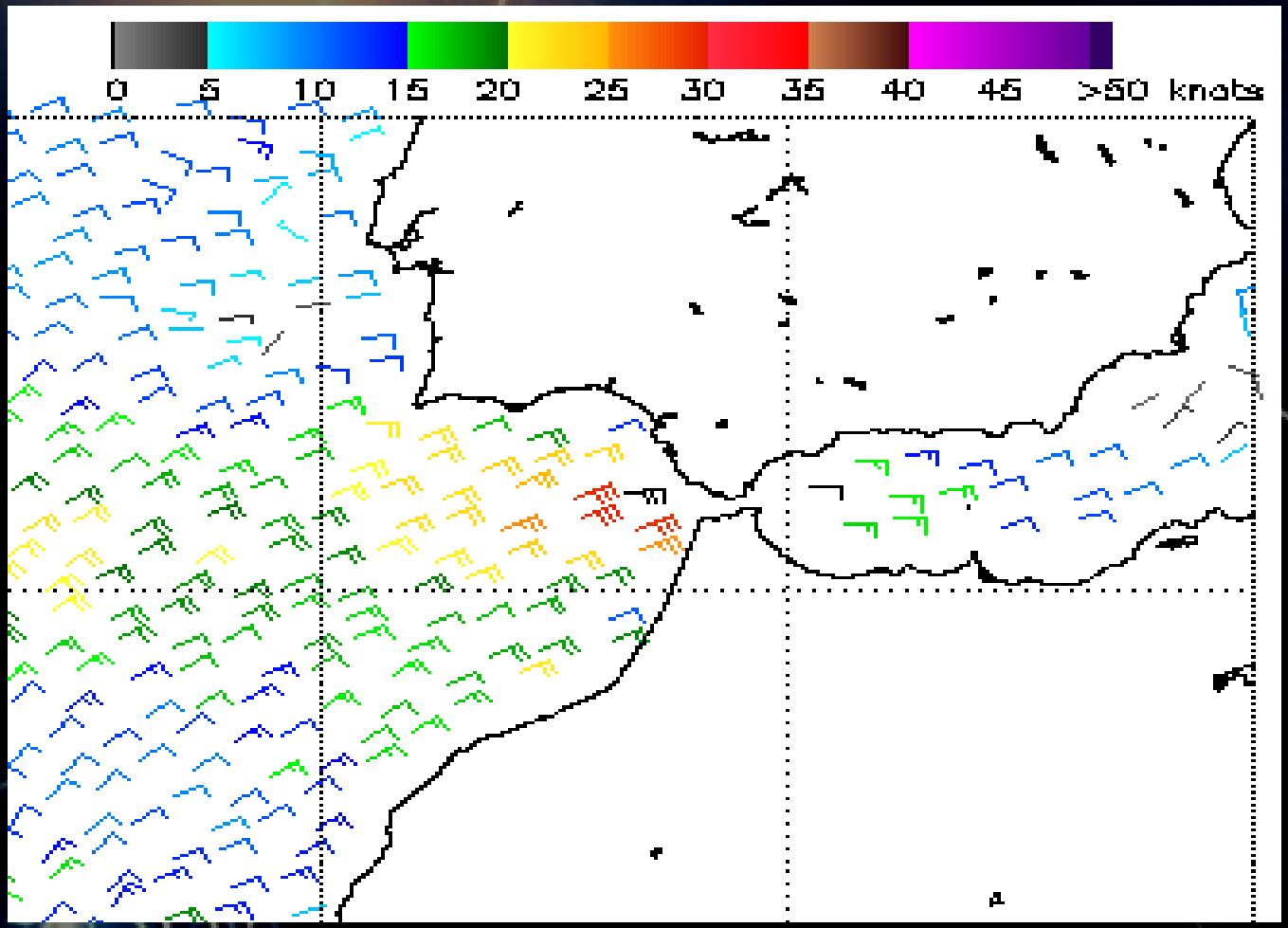



02/01/01 1521Z TRMM WIND
02/01/01 1431Z GMS-5 IR
138E
144E
40N
36N
32N
Tokyo Shelter
Ise Bay
Ku Chan.
Bungo Strait
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
<-- Wind Speed (knots) Rainflag=0 -->
5 10 15 20 25 30 35 40 45

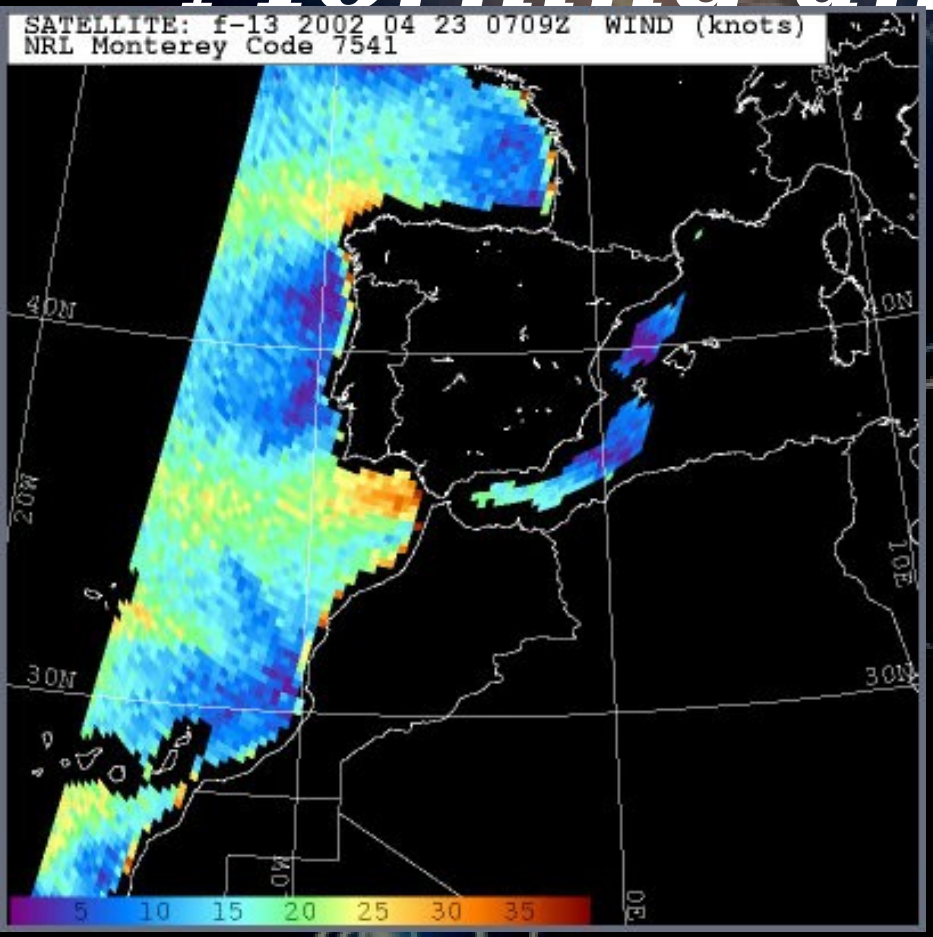

QSCAT Feb 2 21:22 GMT 2001 ascending
0 5 10 15 20 25 30 35 40 45 >50 knots
ISE BAY
GAP WIND
35
30
25
20
15
10
5
0
5
10
15
100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175
19:41
18:00
Note: 1) Times are GMT 2)Times correspond to 20N; right swath edge – time is right swath for overlapping swaths at 20N 3) Feb 2 21:22 GMT 2001–22 hrs
NOAA/NESDIS/Office of Research and Applications

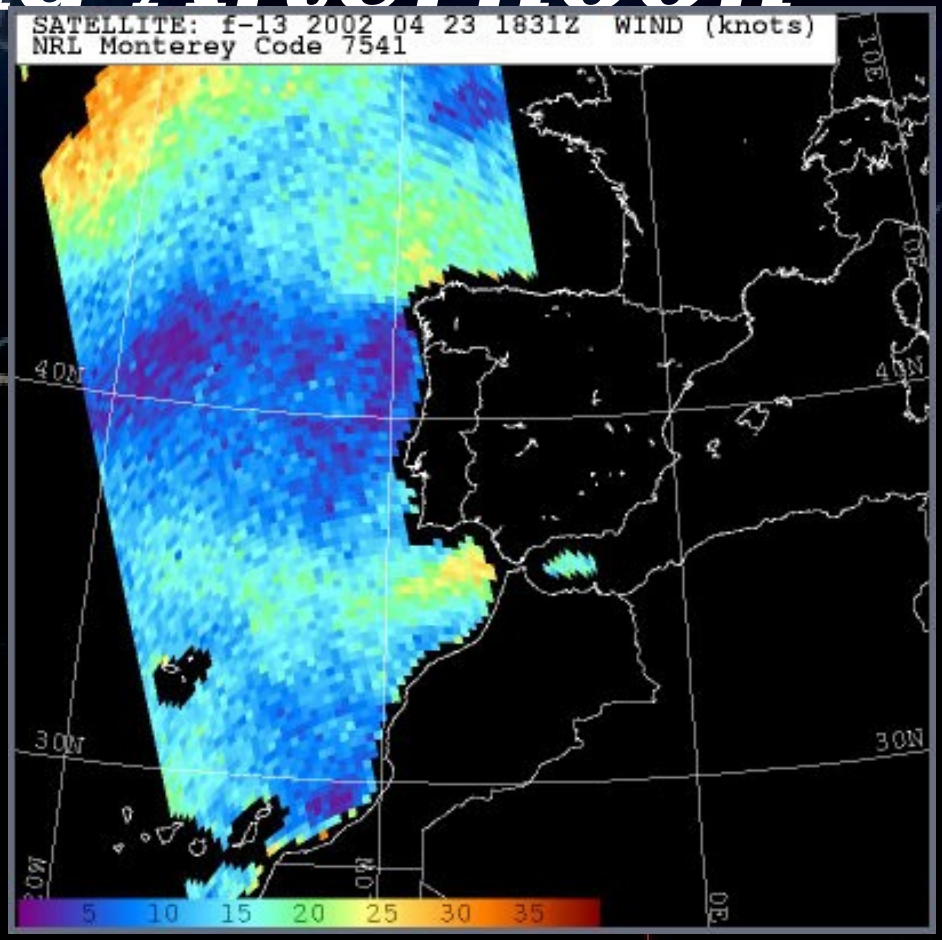

09/12/01 1800Z 20W NARI
09/12/01 2055Z QuikScat
09/12/01 2031Z GMS-5 IR
128E
28N
24N
Naval Research Laboratory http://www.nrlmry.navy.mil/sat_products.html
QuikScat Vectors (knots)
0 5 10 15 20 25 30 35 40 45 50 55 60

Gap Wind Example Scatterometer

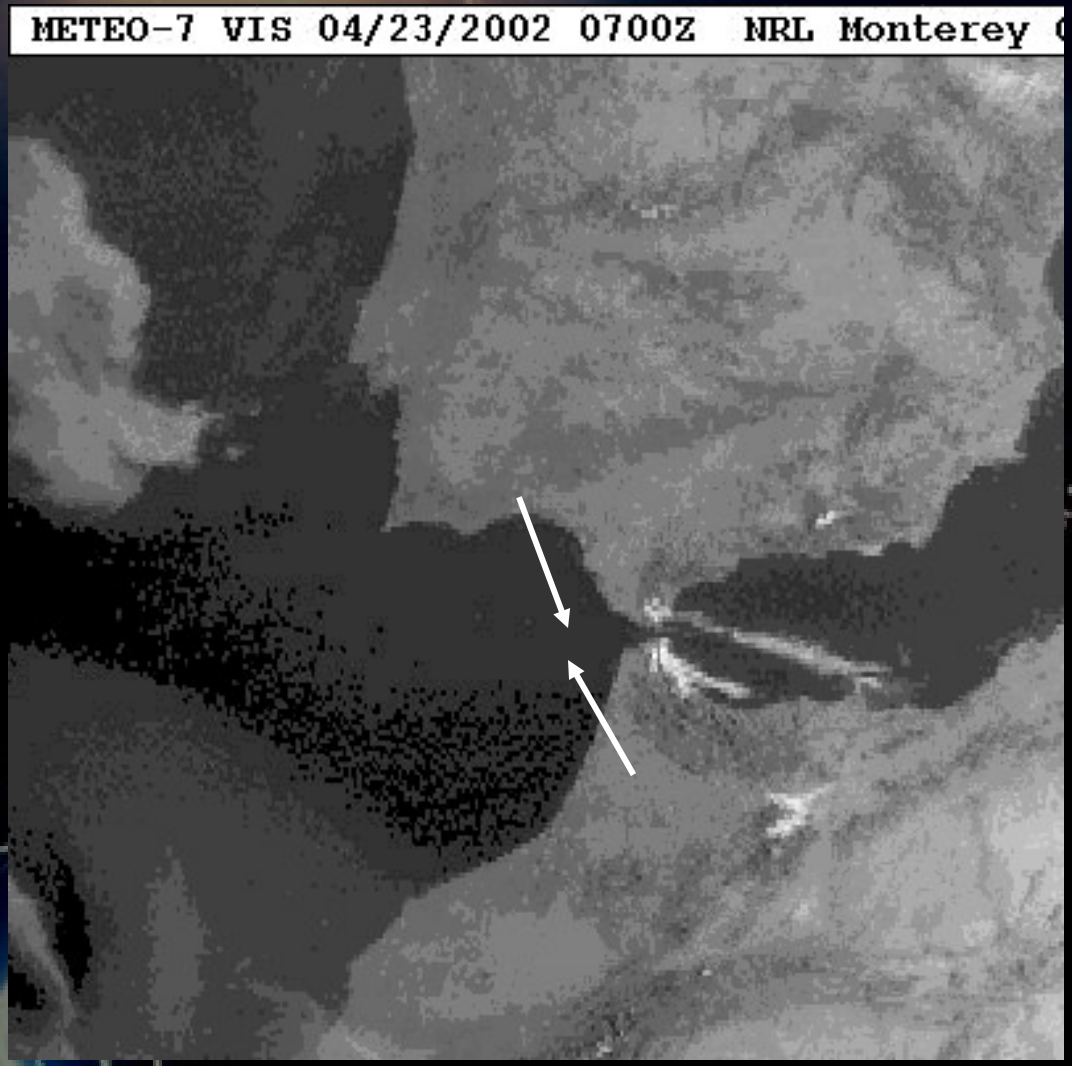


SSM/I Gap Wind Examples Morning and Afternoon





Meteosat 7 Animation



Upcoming Passive Microwave Satellites (Conical)

- SSMIS on DMSP – Wider Swath, higher frequency channels (1800 km swath, late 2002/2003)
- WindSat – Wind Speed and Direction (2003)
- AMSR Instruments on Aqua (May 2002) and ADEOS-II (2003)
- CMIS on NPOESS, Operational Satellite (2008)

Upcoming Active Microwave Satellite

- Seawinds Scatterometer (like QuikScat) ADEOS-II (2003)

Summary

- Active vs. Passive
- Passive
  - Advantages
  - Limitations
  - Microwave retrievals
- LEO
  - Scanning Strategies
  - Sounder vs. Imager
- Current Operational Passive Microwave Satellites

Questions

- APPLICATION: Assign Review Exercise 8.

- EVALUATION: Administer and evaluate Appraisal 302h. Give the Written Test at the end of the unit.